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(September 1955)

SCLEROTIUM ROLFSII SACC. ON JUTE AND ITS PERFECT STAGE

By T. Ghosh and K. V. George, Jute Agricultural Research Institute, Barrackpore, West Bengal

(Received for publication on 10th August 1953)

(With Plates VI-VII)

BOTH the species of jute—*Corchorus capsularis* and *Corchorus olitorius*—are susceptible to *Sclerotium rolfsii* Sacc. which causes ' soft-rot ' of the host. The attack of the fungus is usually limited to the collar region of the plant, i.e. at the ground level. The white, thick, feather-like and flocculent strands of mycelium spread out in all directions and surround the stem of the host, as soon as they come in contact with it. The epidermis and the cortex of the affected part disintegrate very quickly. The fibre bundles are shred (Plate VI) and turn rusty brown; eventually, the stem breaks. The fungus which is chiefly soil-borne, multiplies on plant debris, particularly on old jute stubbles and fallen leaves and perpetuates through sclerotia which are as large or even larger than normal mustard seeds. The sclerotia are white or buff coloured at the initial stages, but they gradually grow bigger in size and turn light brown to tan or chocolate-brown. They are mostly round and regular in shape, but sometimes the size and shape vary. The fungus usually attacks the jute crop from late July onwards. The optimum temperature and humidity for the spread of the disease are 80° to 90°F and 90 to 100 per cent respectively, and the disease thrives well in shade. The disease is fairly within controllable limits at the late stage of crop-growth near about the harvest stage.

While the usual symptoms of the disease are as described above, it has also been noticed at Chinsurah since 1948 that the fungus often attacks the stem much above the ground level. The symptoms in such attacks differ from those which appear when the attack is confined to the collar region. There are distinct concentric rings or zones of alternate shades of deep and light brown round the point of infection and the characteristic feather-like mycelium is not seen in the initial stages (Plate VII, fig. 4). This location of the seat of infection, higher up on stems much above the ground level suggested the presence of an air-borne phase of the fungus, which was expected to be the basidial stage. In August 1949, one badly affected plant of *Corchorus olitorius*, type JRO-753, showed a thin crust of matted mycelium associated with the feather-like hyphal strands and sclerotia of *Sclerotium rolfsii*. On examination it was found to be a condensed mycelial mat with a hymenial layer composed of clavate swollen cells cut off from the ends of fertile hyphae. Some of the fertile cells formed true basidia. The basidia are stout, measuring 13·82 to 15·35 $\mu \times$ 6·91 to 7·67 μ, clavate, bearing 2-4 hyaline, slightly curved, and with tapering sterigmata, each bearing a basidiospore (Plate VII, Fig. 1, 3). The basidiospores measuring 6·14 to 8·44 $\mu \times$ 3·38 μ are hyaline, smooth-walled and obliquely pyriform (i.e. having one side slightly curved inwards with a rather pointed base).

The fungus was isolated on standard potato-dextrose agar and was grown on onion-asparagin-proteose-peptone agar according to formula given by Mundkur [1934]. The cultures were kept at 33°C$\pm$1°C. Mundkur. [1934], Milthorpe [1941] and Venkatakrishnaiya [1946] obtained the perfect stage on this medium, but the authors obtained only the usual sclerotial stage. All attempts to grow the perfect stage in artificial media failed.

In 1950, during the routine study of 'antagonism' of certain moulds and bacteria against *Sclerotium rolfsii* Sacc. (isolated from jute), it was accidentally found that in one petri dish with a combination of *S. rolfsii*, a species of *Aspergillus* and a species of *Bacterium*, a thin chalky white mycelial mat (the perfect form) developed adjoining the rim of the dish on standard potato-dextrose agar. On examination the hymenial layer was found to be less compact (*areolate hymenium*) than that from the natural host. The basidia and basidiospores were identical with those observed in nature (Plate VII, Fig. 2).

The measurements given for basidia, basidiospores and sterigmata by Curzi [1931-32], Mundkur [1934], Venkatakrishnaiya [1946], West [1947] and by the authors are given in Table I.

Table I

Measurements of basidia, sterigmata and basidiospores according to different workers

Described by	Basidia	Sterigmata	Basidiospores
	(*Measurements in microns*)		
Curzi	10—15×4—5	4—5	5—7×2·5—3·8
Mundkur	16·5—39·0×4·2—6·1	..	4·9—9·4×2·6—7·1
Venkatakrishnaiya	6—12×4—6	4	3—4×2—3
West	7—9×4—5	3—4	6—7×3·5—5
Authors	13·82—15·35×6·91—7·67	2·5—4	6·14—8·44×3·38

From Table I it will be seen that the measurements compare close to those given by Curzi and Venkatakrishnaiya both of whom have referred the perfect form to the genus *Corticium*. Moreover, the morphological characters resemble the description given by West [1947] for the strain found on *Ficus pumila* L. He has referred such forms having areolate hymenium, short celled hyphae and stout basidia to the genus *Pellicularia*, and has changed the name '*Corticium rolfsii* (Sacc.) Curzi' to '*Pellicularia rolfsii* (Sacc.) West'. Venkatarayan [1950] has, in a recent paper, proposed the name '*Botryobasidium rolfsii* (Sacc.) Venkatarayan' for the perfect form. But the authors consider that there is sufficient reason to retain the name '*Pellicularia rolfsii* (Sacc.) West' for this fungus, which attacks jute.

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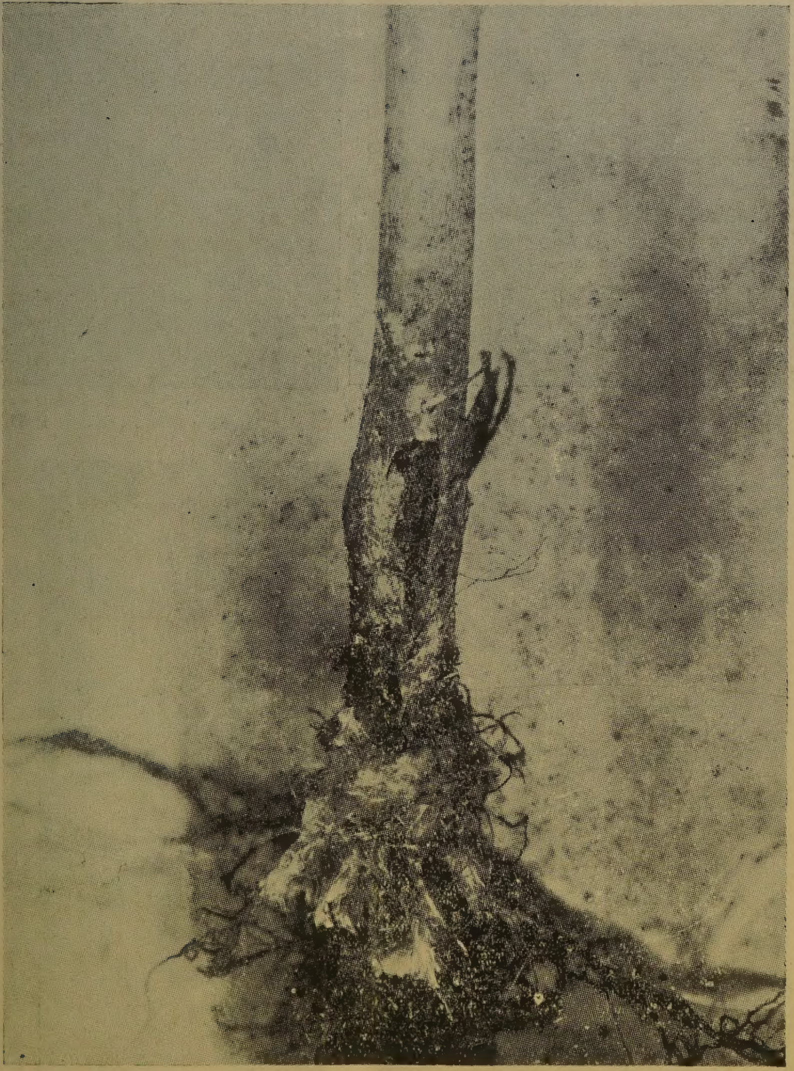

A jute plant with soft-rot : The white feather-like mycelia are visible

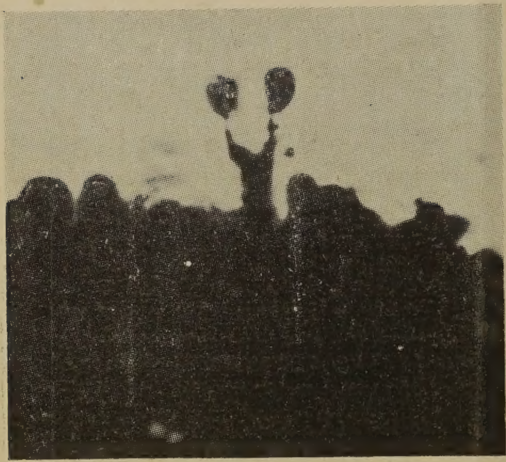

FIG. 1. Basidium from nature on *C. olitorius*

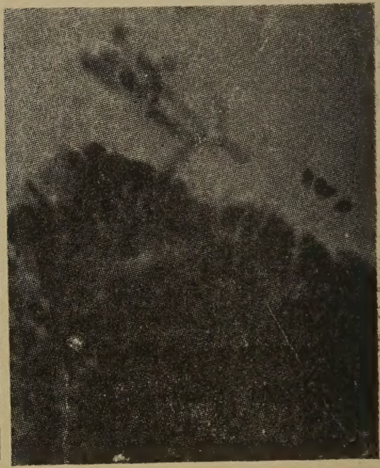

FIG. 2. Basidium from culture on P. D. A.

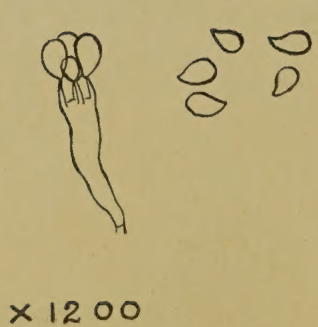

FIG. 3. Basidium showing sterigmata and basidiospores : Camera lucida drawing

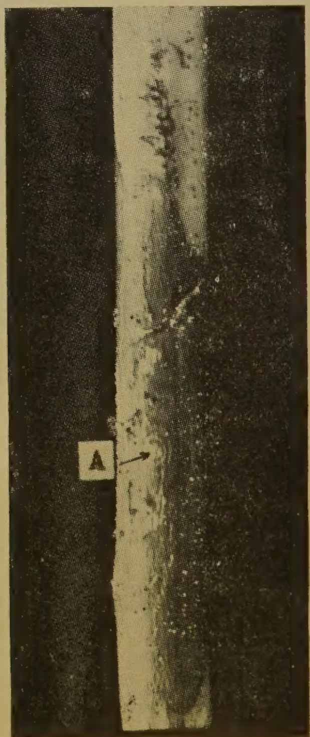

FIG. 4. A—Point of infection ; white granules are rediments of sclerotia

ACKNOWLEDGEMENT

Our thanks are due to Dr B. C. Kundu, Director, Jute Agricultural Research Institute, for encouragement at all stages of the work.

REFERENCES

Mundkur, B. B. (1934). Perfect stage of *Sclerotium rolfsii* Sacc. in culture (Preliminary announcement) *Indian J. agri. Sci.* **4** : 779-781

Millthorpe (1941). Studies on *Corticium rolfsii* (Sacc.) Curzi (*S. rolfsii* Sacc.) etc. *Proc. Linn. Soc., N.S.W. IXVI*, 1-2, 65-75. (*Rev. Appl. Mycol. XXII*, 1943.)

Rogers, D. P. (1943). The genus *Pellicularia. Farlowia*, **1** : 95-118

Venkatakrishnaiya, N. S. (1946). Perfect stage of *Sclerotium rolfsii* Sacc. causing pseudostem rot of plantain (*Musa sapientum*) *Curr. Sci.* **15** : 259

Venkatarayan, S. V. (1950). Notes on some species of *Corticium* and *Pellicularia*. *Indian Phytopath.* **3, 1** : 81-84

West, Erdman (1947). *Sclerotium rolfsii* Sacc. and its perfect stage on climbing fig. *Phytopath.* **37** : 67-69

STUDIES ON THE RELATIVE VALUES OF DIFFERENT PHOSPHATIC MANURES*

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(Received for publication on 9th February 1953)

THE recent work at the Indian Agricultural Research Institute, New Delhi, has indicated that the phosphatic manuring of legumes, specially of berseem (*Trifolium alexandrinum*), helps in increasing the yields and improving the quality of legumes in addition to building up soil fertility which in turn gives higher yields of cereal crops following these phosphate manured legumes.

There are regions in India where soils are deficient in phosphates, as such application of phosphate under Indian conditions is now assuming importance. Phosphates are available in many forms, e.g. indigenous products, such as bones, rock phosphates and trichy nodules ; by-products of iron works such as basic slag and foreign products. Unlike nitrogen, very little information is available on the manuring with phosphates under Indian conditions. The information on the relative value of different forms of phosphate is still meagre. Stewart [1947] while summarising the work on phosphates in India states that apart from few experiments with ammophos, most of the experimental work has been done with superphosphate and bone products, and the results suggest that the former is rather quick acting than the latter. Vyas has suggested the composting of bones with sulphur as a means of increasing their availability to plants, whilst in reference to the manurial value of different mineral phosphates in calcareous soils, Das draws attention to the uncertain and erratic behaviour of superphosphate, and indicates that its manurial value is enhanced when it is applied along with bulky organic manures. In general, however, sufficient data are not yet available to permit of generalization being made either on the relative merits of different forms of phosphates or on the need of pretreatment under different conditions of soils, climate and cropping.

Karrakar *et al.*, [1941] concludes from a trial of five years under field conditions that superphosphate and rock phosphate are equal in their effects on the crops. De Coux *et al.*, [1943] was of the opinion that in acidic soils effect of superphosphate and Renohypeprhosphate was equal but in alkaline soils superphosphate gives better response. Richardson *et al.*, [1945] has shown that in the case of *kudzu* vine various sources (super and basic slag) were equal. Davis [1908] from his experiments on sannhemp and indigo in Bihar stated that with the application of superphosphate, a marked high standard quality was observed. Cook [1931] concluded that various applications of superphosphate on different soils resulted in better quality of alfalfa. West [1938] and Gericke [1938] simultaneously noted that

*Shri R. A. Gupta and S. S. Pathak, post-graduate students worked on the above problem in the *rabi* 1948 and the *rabi* 1950 respectively, and Shri L. L. Relwani, Research Assistant, assisted during the *rabi* 1949.

phosphatic fertilizers improved the quality of legume fodder. Parr and Pose [1945], and Parr and Sen [1947] concluded that the application of phosphatic fertilizers to berseem improved the quality of fodder.

Parr and Bose [1947] and Parr and Sen [1948] have shown that the application of phosphate to berseem builds up soil fertility to enable cereal crops to be grown without manuring. A Committee Report [1918] of the Board of Agriculture for Scotland stated that the effect of phosphatic fertilizers was not exhausted in the first year and that it lasted for three seasons. It also laid down that half of the superphosphate remained unexhausted after first season, one-fourth after the second season and one-eighth after the third season.

Hartwell and Deman [1915] have shown that crops continue to show effect of phosphates even after nine years of cropping. Gordon [1918] reported that the residual effect on the following crop of wheat was sufficient to pay for the original cost of the applied phosphate. Many workers like Lohnis [1926], Bailey *et al.*, [1930] Nicol [1933], and Lyon [1936] have proved that legumes enrich the soil, the residual effect of which is beneficial to the succeeding non-leguminous crops.

It will be seen that very little information is available on the relative value of different forms of phosphate and their residual value.

Stewart [1947] has also laid stress on the study of relative value of different forms of phosphatic manures under Indian conditions.

It was, therefore, considered necessary to know the value of various phosphatic manures from the points of increased production and quality, their residual effect and national planning of manufacture of phosphatic manures.

Accordingly, an experiment was laid down to study the relative value of as many different forms of phosphate with reference to their direct effect on berseem, residual effect on maize, berseem and maize, effect on the quality of berseem fodder, and lastly the economics.

The results obtained are described in this article.

Methods and materials

The experiment was started in 1948 and was concluded in 1950-51. The studies on residual effect continued upto 1952. In each year 1948-49, 1949-50 and 1950-51, experiment was conducted on a different block.

Berseem was selected for study as it has been reported to respond to the application of phosphates and build up soil fertility.

It was intended to test as many forms of phosphatic manures as could possibly be done. Accordingly, in 1948 only eight forms were tested while in 1949 and 1950 the number was ten. The different forms of phosphatic fertilizers under test are described below :

(A) *Renohyperphosphate* : It is a recent introduction in India by Messrs. Louis Dreyfus & Co. Ltd., Madras. It contains 30 per cent P_2O_5 in soluble form. Its price is not known.

(B) *Ammophosphate* : This fertilizer contains both nitrogen and P_2O_5 and is available in different grades, some of which are as follows :

	(Per cent nutrients)	
Grade	P_2O_5	N
1	29·0	16·0
2	50·0	20·0
3	48·0	10·0
4	20·0	20·0

In this experiment grade No. 1 was used. The cost of this grade is Rs. 13-8-0 per maund approximately.

(C) *Ammonium sulphate* : It contains 20·0 per cent nitrogen. Though it is not a phosphatic manure, it was included to see if the nitrogen in the ammophos showed any effect. It was added at the rate of nitrogen as found in ammophosphate. This worked out to be about 64 lb. N per acre.

(D) *Bonemeal* : This is finely ground bones from which fat is removed and is an indigenous product. It contains a little nitrogen also. The P_2O_5 in it is in insoluble form and varies between 22-24 per cent. The cost of bonemeal is Rs. 7 per maund approximately.

(E) *Bone superphosphate* : It is manufactured from bones by D. C. M. Chemical works, Delhi. It contains 17-22 per cent P_2O_5 in soluble form. Its value is Rs. 11 per maund.

(F) *Double or triple superphosphate* : This is manufactured from rock phosphate and is imported into India. The content of P_2O_5 in it varies between 40-45 per cent. It costs Rs. 18 per maund approximately.

(G) *Rock phosphate* : It is an indigenous product and is available from Rakka mines (Bihar). It is powdered finely before use. The P_2O_5 content varies between 16-24 per cent and is in insoluble form. The cost is Rs. 12-8-0 per maund approximately.

(H) *Bonemeal sulphur compost:* It is a compost of bonemeal with sulphur, sand and charcoal. A cultivator can easily prepare this by using the following proportions :

Bonemeal	10·0 maunds
Sulphur	2·5 ,,
Charcoal dust	1·6 ,,
Sand	10·0 ,,
Dry soil	1·0 ,,
Water	Till it is moistened

This product consists of both soluble and insoluble P_2O_5. It takes about three weeks to prepare this compost. The contents of P_2O_5 vary between 5-8 per cent. The cost comes to Rs. 4-8-0 per maund approximately.

(J) *Trichy phosphate nodules* : It is an indigenous product and is a type of rock phosphate found in Trichinopoly. It is finely powdered before use. It is very hard and offers great difficulty in grinding. It contains P_2O_5 in insoluble form. The P_2O_5 contents varies between 24-28 per cent and the cost per maund is Rs. 3-8-3 approximately.

(K) *Agrophosphate*
(L) *Selectophosphate*
These are recent introductions in India by Messrs. Louis Dreyfus and Co. Ltd., Madras. The P_2O_5 content is about 25 per cent. These are reported to be easily, rapidly and entirely assimilated. It is reported that these forms do better in acid soils. Price is not known.

(M) *Magnesium phosphate :* This was received through the Government of India, Ministry of Agriculture, from Belgium. It contains 28·5 per cent P_2O_5 in soluble form and is good for acidic soils. The details of the experiments are as follows :

Item	Year		
	1948	1949	1950
Location	Main Block 8A	Main Block 8B	Main Block A2
Rotation	Berseem-maize-berseem-maize	Berseem-maize-berseem-maize	Berseem-maize-berseem-maize
Layout	Randomised block system	Randomised block system	Randomised block system
Replications	8	6	6

Item	Year 1948	1949	1950
Treatments	A. Renohyperphosphate	A. Renohyperphosphate	A. Renohyperphosphate
	B. Ammophosphate	B. Ammophosphate	B. Ammophosphate
	C. Ammonium sulphate	C. Ammonium sulphate	C. Ammonium sulphate
	D. Bonemeal	D. Bonemeal	D. Bonemeal
	E. Bone superphosphate	E. Bone superphosphate	E. Bone superphosphate
	F. Double or triple superphosphate	F. Double or triple phosphate	F. Double or triple superphosphate
	G. Rock phosphate	G. Rock phosphate	G. Rock phosphate
	H. Bonemeal sulphur compost	H. Bonemeal sulphur compost	H. Bonemeal sulphur compost
	J. Trichy nodules	J. Trichy nodules	K. Agrophosphate
		K. Agrophosphate	L. Selectophosphate
		L. Selectophosphate	M. Magnesium phosphate
	I. Control	I. Control	I. Control
Size of bed	0·025 acre	0·022 acre	0·025 acre
Date of sowing	2/3—11—48	4/5—11—49	8/9—11—50
Seed rate	30 lb./acre	30 lb./acre	30 lb./acre
Number of cuttings obtained	6	6	6
Number of irrigations	16	13	15
Soils analysis *			
Nitrogen percentage	0·0602	0·055	0·036
Total P_2O_5	0·108	0·16	0·068
Available P_2O_5 per cent	0·0235	0·018	0·0172
Physical texture	Loam	Loam	Loam
Dose of P_2O_5 per acre	80 lb.	80 lb.	80 lb.
Method and time of application of phosphate	Broadcast—applied to first berseem crop in rotation at the time of sowing	Broadcast—applied to first berseem crop in a rotation at the time of sowing	Broadcast—applied to first berseem crop in a rotation at the time of sowing

*These were got analysed in the Division of Soil Science and Agricultural Chemistry, Indian Agricultural Research Institute, New Delhi.

Diseases and pests : There was no disease or pest during the course of the experiment.

Harvesting : As soon as the crop was ready, it was harvested and the yield of each plot was recorded separately for each cutting. After the harvest of last cutting in May each year, the land was ploughed and prepared for sowing maize fodder at the end of June or early July each year. Maize fodder was removed by the end of August or early September and land was prepared for sowing berseem in October. The yield data for maize and berseem fodders were recorded separately for each plot to study the residual effect of the application of different forms of phosphatic manures.

Experimental findings and Discussion

The results obtained during the course of the experiment are given in Table I.

TABLE I

Effect of different phosphates on the yield of berseem fodder

Treatment	Yield of green fodder in maunds per acre			Weighted average of 3 years for common treatments only
	1948-49	1949-50	1950-51	
A. Renohyper phosphate	965·3	885·8	201·4	712·2
B. Ammophosphate	1106·2	1044·7	472·9	897·7
C. Ammonium sulphate	1006·2	960·5	276·2	773·7
D. Bonemeal	1053·7	858·3	336·6	780·0
E. Bone superphosphate	1000·1	888·0	264·6	746·5
F. Double or triple superphosphate	1072·2	920·1	225·8	772·6
G. Rock phosphate	1048·4	917·4	173·6	746·7
H. Bonemeal sulphur compost	1069·3	954·4	230·9	783·2
I. Control	1014·3	829·0	250·7	729·7
J. Trichy nodules	963·0	865·7	..	..
K. Agrophosphate	..	936·4	213·9	..
L. Selectophosphate	..	894·8	162·5	..
M. Magnesium phosphate	..	..	174·2	..
S. E.	34·96	31·17	40·92	21·44
C. D. at 5 per cent	..	88·37	115·73	59·97

TABLE II

Response of different forms of phosphates

Treatment	Response in maunds per lb. of P_2O_5			Average of three years of common treatment
	1948-49	1949-50	1950-51	
A. Renohyperphosphate	0·61	0·71	0·62	0·22
B. Ammophosphate	1·15	2·70	2·78	0·86
C. Ammonium sulphate	..	..	..	..
D. Bonemeal	0·49	0·37	1·07	0·65
E. Bone superphosphate	0·18	0·74	0·17	0·21
F. Double or triple superphosphate	0·72	1·14	0·31	0·54
G. Rock phosphate	0·43	1·11	0·96	0·21
H. Bonemeal sulphur compost	0·69	1·57	0·25	0·67
I. Control	..	..	..	..
J. Trichy nodules	0·64	0·46	..	..
K. Agrophosphate	..	1·34	0·46	..
L. Selectophosphate	..	0·82	1·10	..
M. Magnesium phosphate	..	..	0·96	..

The results in Table I and II show that during 1948-49, the treatment of ammophosphate has given the highest yield per acre and also the highest response per pound of P_2O_5 applied. The treatments of renohyperphosphate, bone super and Trichy nodules showed no useful effect. The treatments of superphosphate, bonemeal compost, bonemeal and rock phosphate gave higher yields than the control, but the differences were not significant. The yield and response in the case of superphosphate and bonemeal compost were nearly equal, but slightly more than in the case of bonemeal and rock phosphate which showed equal performance. During the year 1949-50, treatment of ammophosphate gave significantly higher yields than the other forms of phosphates and the highest response. Treatments of bonemeal compost, renohyperphosphate, agrophosphate, superphosphate and rock phosphate were nearly equal in performance both from the point of view of yield and response and are significantly superior to control. The treatments of selectophosphate, bone super, Trichy nodules and bonemeal have also given higher yields than the control but the differences are not significant. During 1951-52, the treatment of ammophosphate has given the highest yield and response and is significant over all other

forms of phosphates. The treatments of bonemeal and bone super have given higher yields than control, but the differences are not significant. The rest of the treatments of different forms of phosphates have given lower yields than control but the differences are not significant.

The average effect of three years shows that the treatment of ammophosphate has given the highest yield and is significantly best of all the treatments. All other forms excepting renohyperphosphate have given higher yields than control but the differences are not significant. Treatment of renohyperphosphate is significantly inferior to bonemeal compost, bonemeal and superphosphate. As regards response, treatment of ammophosphate has given the highest response followed by bonemeal compost, bonemeal and superphosphate. Rock phosphate and bone super have given nearly equal response while the response with renohyper is in the negative.

It is also clear that the treatment of ammonium sulphate has shown significantly higher yield than the control in one out of three years. This treatment has also given higher yield than most of the phosphates in different years, indicating thereby the importance of nitrogen. It is thus clear that the treatment of ammophosphate (containing both nitrogen and P_2O_5) is the best. Among other forms of phosphates, bonemeal compost, bonemeal and superphosphate can be classed together regarding their effect on yield and response. Again, rock phosphate, bone and super can be grouped together as regards their effect. The remaining forms can be grouped as showing least or no performance.

TABLE III

*Effect of application of different forms of phosphate on the quality of berseem fodder**

Treatment	Average percentage composition of berseem on dry basis								
	1948-49			1949-50			Average of two years		
	Nitrogen	P_2O_5	Ca	Nitrogen	P_2O_5	CaO	Nitrogen	P_2O_5	CaO
A. Renohyper phosphate	4·27	0·77	2·9	3·81	0·64	2·47	4·04	0·70	2·68
B. Ammophosphate	4·00	0·93	3·12	3·87	0·79	2·75	3·93	0·86	2·93
C. Ammonium sulphate	3·87	0·73	2·88	3·72	0·62	2·19	3·80	0·69	2·53
D. Bonemeal	4·16	0·82	2·73	3·95	0·68	2·64	4·05	0·75	2·69
E. Bone super phosphate	4·31	1·00	3·26	3·96	0.67	2·54	4·13	0·88	2·90
F. Double or triple super phosphate	3·62	0·76	2·94	4·02	0·83	2·59	3·82	0·80	2·76
G. Rock phosphate	4·20	0·93	3·00	3·87	0·70	2·74	3·99	0·82	2·87
H. Bonemeal sulphur compost	4·00	0·83	2·97	3·56	0·71	2·64	3·78	0·77	2·80
I. Control	3·67	0·73	2·66	3·56	0·65	2·67	3·61	0·69	2·66
J. Trichy nodules	4·63	0·79	2·96	3·59	0·63	2·57	4·11	0·71	2·76
K. Agrophosphate	..	..	..	3·92	0·77	2·74	3·92	0·77	2·74
L. Selectophosphate	..	..	..	4·03	0·75	2·56	4·03	0·75	2·56

*The samples of berseem were got analysed in the Division of Soil Science and Agricultural Chemistry at the Indian Agricultural Research Institute, New Delhi.

Figures in Table III indicate that as a general rule application of P_2O_5 to berseem improves quality of berseem fodder. The effect of different forms is, however, different.

Average figures of two years show that the application of bone super has given the best quality of berseem, followed by ammophosphate, rockphosphate and superphosphate as regards all ingredients are concerned.

The application of ammonium sulphate has increased slightly the nitrogen content of the fodder but there is no increase in P_2O_5 and CaO contents.

TABLE IV

Recovery of P_2O_5 from average yield of 1948-49 and 1949-50

Treatment	Average yield of dry matter in md. per acre	Quantity of P_2O_5 recovered in the yield in lb.	Increase over control in lb.	Percentage recovery
A. Renohyper phosphate	190·5	109·35	5·07	6·35
B. Ammophosphate	215·1	151·69	47·41	59·25
C. Ammonium sulphate	196·7	111·30	7·02	8·75
D. Bonemeal	191·2	125·09	20·81	26·05
E. Bone superphosphate	188·8	136·24	31·96	39·95
F. Double or triple superphosphate	199·4	130·81	26·53	33·15
G. Rock phosphate	196·6	132·19	27·91	34·90
H. Bonemeal sulphur compost	202·4	127·79	23·51	29·40
I. Control	184·3	104·28	..	..
J. Trichy nodules	182·9	106·48	2·20	2·75

It will be seen from Table IV that the recovery of added phosphate was 59·25 per cent in the case of ammophosphate and 2·75 per cent in the case of Trichy nodules. Bone super, rock phosphate, superphosphate, bonemeal compost and bonemeal gave recovery percentages of 39·95, 33·15, 29·40 and 26·05 respectively.

Residual effect : Berseem was manured with different forms of phosphates during three years, 1948, 1949 and 1950, in three different blocks. In each block after the harvest of manured berseem, the following cropping was done :

Maize for fodder—berseem for fodder—maize for fodder.

The results of different crops in each block are summarised in Tables V, VI and VII.

TABLE V

Residual effect of different forms of phosphates in Block No. 1 where berseem was manured in 1948-49

Treatment	Yield of green fodder in md. per acre		
	Maize 1949	Berseem 1949-50	Maize 1950
A. Renohyperphos	196	1,038	165
B. Ammophos	211	1,139	173
C. Ammonium sulphate	176	1,063	197
D. Bonemeal	183	1,067	183
E. Bone super	193	1,040	219
F. Triple super	188	1,092	203
G. Rock phosphate	186	1,076	188
H. Bonemeal compost	207	1,097	204
I. Control	173	1,067	212
J. Trichy nodules	192	1,042	164
'F' Test	Not sig.	Not sig.	Not sig.
S. Em.	15·36	30·31	41·15

TABLE VI

Residual effect of different forms of phosphates in Block No. II where berseem was manured in 1949-50

Treatment	Yield of green fodder in md. per acre		
	Maize	Berseem	Maize
	1950	1950-51	1951
A. Renohyperphos	155	803	265
B. Ammophos	166	942	299
C. Ammonium sulphate	143	886	306
D. Bonemeal	149	845	301
E. Bone super	124	874	278
F. Triple super	113	826	258
G. Rock phosphate	135	837	259
H. Bonemeal compost	143	815	259
I. Control	136	832	265
J. Trichy nodules	147	881	302
K. Agrophosphate	171	828	331
L. Seloto phosphate	144	817	282
'F' Test	Not sig.	Not sig.	Not sig.
S. Em.	23·51	43·03	34 23

TABLE VII

Residual effect of different forms of phosphates in Block No. III where berseem was manured in 1950-51

Treatment	Yield of green fodder in md. per acre		
	Maize	Berseem	Maize
	1951	1951-52	1952
A. Renohyperphos	194	710	485
B. Ammophos	183	743	445
C. Ammonium sulphate	177	742	413
D. Bonemeal	192	664	469
E. Bone super	182	717	388
F. Triple super	166	702	422
G. Rock phosphate	168	700	495
H. Bonemeal compost	216	659	378
I. Control	167	759	376
J. Trichy nodules	..	..	..
K Agrophosphate	218	741	412
L. Selectophosphate	177	715	413
M. Magnesium phosphate	153	673	413
'F' Test	Not sig.	Not sig.	Not sig.
S. Em.	46·69	32·79	26·59

It will be seen from Tables V, VI and VII, that the differences amongst the various treatments, so far as residual effect is concerned, are not significant for any of the crops. This has been confirmed during all the three years at all stages. Though the differences are not statistically significant, yet the results of three years have shown that the differences exist amongst various treatments and that these differences have been confirmed from year to year.

It will be seen that the differences are more marked on the first crop of maize while later on the effects get considerably diminished.

Amongst the different forms of phosphates, ammophosphate, bonemeal compost and agrophosphate appear to show better residual effect on the first maize crop as compared to other forms.

Average residual effect of common treatments in different blocks is shown in Table VIII.

TABLE VIII

Average weighted residual effect of different forms of phosphate

Treatment	Average weighted yield of green fodder (3 crops) in maunds per acre in some of the common treatments only		
	Maize	Berseem	Maize
A. Renohyper phosphate	183·1	869·1	291
B. Ammophos	189·1	961·1	292·4
C. Ammonium sulphate	166·4	913·6	294·5
D. Bonemeal	175·5	879·5	304·2
E. Bone super	169	893·3	287·4
F. Superphosphate	158·9	895·2	285·2
G. Rock phosphate	165·3	891·5	274·4
H. Bonemeal compost	190·5	881·0	272·7
I. Control	160·1	904·1	277·1
'F' Test	Sig.	Not sig.	Not sig.
S.E.m.	6·2	16·9	17·33
C. D. at 5 per cent	18·5	..	..

It will be seen from Table VIII that the differences are more marked on the first crop of maize. Bonemeal compost has shown the highest residual effect on the first crop and the differences are significant over super, control, rock phosphate, bone super and ammonium sulphate. The next is ammophosphate and renohyper phosphate which have also given significantly higher yield than super, control, rock phosphate, super and ammonium sulphate. The treatment of bonemeal has also given higher yield but the differences are not significant. Differences between other treatments are not significant.

The differences between treatments and control narrow down with second and third crop and there is hardly any residual effect seen in the second and third crop of all the forms. Ammophosphate treatment has given the best results with all the three residual crops.

The long established belief that the effect of phosphates continues longer than one year and that it has residual effect on the succeeding crop is not clearly borne out from the above figures.

Economics

The study of manurial value of any fertilizer is incomplete without its economics. Attempt has been made to work out economics of some of the common treatments during the course of the experiment. In working out economics, the cost of the fertilizers and their application has been deducted from the value of increase over the control. The produce is valued at market rates. Economics has been worked out both from the direct and residual effect combined.

The results obtained are given in Tables IX and X.

Table IX

Economics of different phosphatic manures (direct effect only)

Treatment	Average yield in md. per acre	Increase over control in md.	Value of increased fodder at Rs. 2 per md.	Cost of manure added in rupees plus cost of application	Net profit or loss in rupees
B. Ammophosphate	874·60	179·60	359·20	69·00	290·20
C. Ammonium sulphate	747·80	49·80	99·60	65·50	34·10
D. Bonemeal	749·60	51·60	103·20	32·10	71·10
E. Bone superphosphate	717·60	19·60	39·20	56·50	17·30
F. Double or triple superphosphate	739·40	41·40	82·80	46·50	36·30
G. Rock phosphate	713·10	15·10	30·20	5·20	25·00
H. Bonemeal sulphur compost	751·50	53·50	107·00	56·50	50·50
I. Control	698·00	..	..	..	..

TABLE X

Economics of different phosphatic manures (direct and residual effect combined)

Treatment	Average total yield in md. per acre of all the 4 crops (manured berseem and 3 unmanured crops)	Increase over control	Value of increase in rupees per acre	Cost of manure added plus cost of application in rupees per acre	Net profit or loss in rupees per acre during the cycle
B. Ammophosphate	2307·6	285·6	571·2	69·0	502·2
C. Ammonium sulphate	2096·8	74·8	149·6	65·5	84·1
D. Bonemeal	2101·6	79·6	159·2	32·1	127·1
E. Bone superphosphate	2055·6	33·6	67·2	56·5	10·7
F. Double or triple superphosphate	2062·4	40·4	80·8	46·5	34·3
G. Rock phosphate	2031·1	9·1	18·2	5·2	13·0
H. Bonemeal sulphur compost	2077·5	55·5	111·0	56·5	54·5
I. Control	2022·0	..	..	..	..

In working out the economics, the cost of manures and their application has been deducted from the value of increase over the control, the produce valued at market price. It will be seen from data under Tables IX and X that the application of ammophosphate gives the highest net returns followed by bonemeal, bonemeal compost, superphosphate and rock phosphate. The application of ammonium sulphate is also economical.

DISCUSSION

Effect of different phosphatic manures (direct effect)

The work conducted during 1948-50 has shown that the application of ammophosphate has given the best results over all other forms of phosphates tried. The superiority of ammophosphate over other forms of phosphate is due to the fact that it contains nitrogen in addition to P_2O_5 and its better performance than ammonium sulphate is due to the fact that it contains P_2O_5 in addition to nitrogen.

Walkar [1931] trying ammophosphate as a fertilizer for tropical soils of India and Ceylon found that small application of nitrogen helps materially in making good growth during early stages, while heavy application is not necessary.

Sen and Bains [1951] have shown that among phosphatic fertilizers such as ammophosphate, superphosphate, basic slag and bonemeal, best response was given by ammophosphate. Annual reports of the Division of Agronomy, I.A.R.I., New Delhi [1950, 1951], have also shown that the application of ammophosphate to berseem has always given better results than the application of P_2O_5 in the form of superphosphate and rock phosphate.

Chopra [1950] has shown that in the Punjab, berseem needs application of nitrogen and phosphate, and the recommended dose is 80 lb. of nitrogen per acre in the form of ammonium phosphate. The superiority of ammonium phosphate is, therefore, established.

Bonemeal compost, bonemeal, superphosphate and rock phosphate are nearly equal, though bonemeal and its products have given slightly higher yields and profits.

Renohyperphosphate, agrophosphate and selectophosphate do not exhibit any large differences.

Vyas [1927] working on phosphates has shown that application of bonemeal compost gives better yield of potato than superphosphate. Burgevin [1933] concluded that the practice of applying small quantity of nitrogen to encourage early growth is rational. Karrakar *et al.*, [1941] concludes from a trial of five years that under field conditions, superphosphate and rock phosphate are equal. Bausins [1941] reported that ammonium sulphate increased yields of both seed and hay of clover.

De coux *et al.*, [1943] were of the opinion that in acidic soils effect of superphosphate and renohyperphosphate was equal but in alkaline soils superphosphate gave better response.

Richardson *et al.*, [1945] have shown that in the case of *kudzu* vine, various sources (super and basic slag) were equal. Parr and Bose [1945] in their trials revealed that nitrogenous fertilizers were without effect on cowpeas and berseem at the Indian Agricultural Research Institute, New Delhi.

The slightly better results with bonemeal compost and bonemeal over superphosphate are due to the presence of small amounts of nitrogen in bonemeal and bonemeal compost. The slightly better response of superphosphate over renohyperphosphate, selectophosphate and magnesium phosphate is due to alkaline nature of the soil.

The smaller increases due to superphosphate, bonemeal compost and other phosphates excepting ammonium phosphate over the control appear to be due to the fact that the soils on which experiment was conducted contained just sufficient quantity of phosphates. Singleton [1945] concluded that the application of phosphate does not show response with alfalfa when sown on new lands having sufficient P_2O_5 supply. The finding that the application of sulphate of ammonia alone can give as good yields as in the case of superphosphate along with berseem does not agree with the finding of Parr and Bose [1945]. The various workers in different parts of the world have, however, shown that the application of small quantity of nitrogen to legumes is rational. It has also been pointed out that with abundant supply of other minerals, the application of nitrogen helps in increasing the yield

of clover. It, therefore, appears that in the present experiment as the amount of other minerals was adequate, the application of nitrogen alone in the form of ammonium sulphate showed its beneficial effect.

Effect on the quality of berseem

The results have shown that the application of phosphate has helped in producing berseem fodder of better quality. The results obtained thus confirm the previous findings of other workers. There is, however, no information available as to the behaviour of different forms of phosphates towards improvement of quality of fodder. This trial indicated that ammophosphate gives a recovery of 59·25 per cent P_2O_5 as compared to 26-40 per cent in the case of other forms. Trichy nodules, however, give a very low recovery of about 2·75 per cent. Different forms also affect differently the quality of fodder. Some of the forms which have given comparatively better quality of fodder are ammophosphate and bone super.

As regards quality of fodder is concerned, application of sulphate of ammonia has given no advantage over control.

Residual effect

The long established belief that the effect of phosphates continues longer than a year and that the phosphate manuring of berseem has a residual effect on the succeeding crop is not clearly borne out from the result of this experiment.

It will be seen from the figures of available P_2O_5 in soil, that the soils were already fairly well supplied with phosphates. It is, therefore, likely that on such soil phosphate manuring of berseem may not show much residual effect.

Agarwal *et al.*, [1951] working on phosphate manuring of crops at Kanpur stated that when berseem was manured with super, bone super and ammonium phosphate, there was very little increase in yield due to the phosphate manuring of both in regard to berseem and the following unmanured crop of wheat.

SUMMARY AND CONCLUSION

An experiment to study the effect of different forms of phosphatic fertilizers was laid down in 1948 and was continued till 1951. The effect has been studied on berseem (*Trifolium alexandrinum*). The studies have been made on the yield response, quality and economics of different treatments. The results of three years reveal the following :

1. That under the soil and climatic conditions, application of both nitrogen and P_2O_5 is necessary for berseem.
2. Of the forms of phosphates tried, ammophosphate has given outstanding results.
3. Bonemeal compost, bonemeal, superphosphate and agrophosphate are nearly equal. Trichy nodules have not shown much response.
5. There are indications that application of nitrogen in small quantity is rational.
6. Soils having adequate supplies of P_2O_5, may not show response to application of P_2O_5 only.

7. Applications of ammophosphate and bone super give yields of the best quality.
8. Recovery of P_2O_5 in the case of ammophosphate is 59·25 per cent while in other forms excepting renohyper and Trichy nodules, it varies between 20 to 40 per cent.
9. There is no significant residual effect of different forms of phosphates applied to berseem in general. Ammophosphate, bonemeal and bone-meal compost have shown some residual effect but differences are not significant. The residual effect is more marked and is significant with the first crop of maize after manured berseem. The treatment of ammophosphate shows vast differences of all the treatments.
10. From economic point of view ammophosphate is the best.
11. Results of the direct and residual effects show that the treatment of ammophosphate is the best of all.

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References

Agarwal, R. R. *et al.*, (1951). *Agri. & Anim. Husb.*, U.P., 4(3)
Bailey, R. Y. *et al.*, (1930). *A. I. Agri. Exp. Sta. Bull.* 232
Bausina, K. F. (1941). *Vest. Seljkohoz nant, Karmodabranci*, 2, 45-49
Chopra, J. D. (1950). *Punjab Farmer*, April 1950
Cook, R. L. (1931). *Mich. Agri. Expt. Sta. Bull.* 13
Das, S. (1944). *Indian J. agric. Sci.* 14
De Cour, L. *et al.*, (1943). *Publ. Inst. Belign. Amelior Better* 484 : 235-256
Davis, W. A. (1918). *Pusa. Agri. Res. Inst. Publ.*, 81
Gericke, S. (1938). *Phosphate Fertilizing* and *national phosphorus*, 7 : 470-486
Gardon, G. S. (1918). *J. Dept. Agri. Victoria*, 16 : 610
Hart Well, B. L. *et al.*, (1915). *R. I. Spt. Exp. Bull.* 163
I.A.R.I. (1951). *Annual Report, Division of Agronomy, Indian Agricultural Research Institute*
I.A.R.I. (1952). *Annual Report, Division of Agronomy, Indian Agricultural Research Institute*
Karrakar, P. F. *et al.*, (1941). *Kentucky Agri. Exp. Sta. Bull.* 413 : 57-86
Lohino, F. (1926). *Soil. Sci.* 22 : 236
Lyon, T. L. (1936). *Corn. Univ. Agri. Exp. Sta. Bull.* 845
Nicol, A. (1933). *Emp. J. Exp. Agri.* : 22
Parr, C. H. and Rose, R. D. (1945). *Indian Fmg.* 6
—— (1947). *Ibid.*, 8
—— Sen, S. (1948). *Ibid.*, 9
Richardson, E. I. *et al.*, (1945). *J. Amer. Soc. Agron* : 39(9)
Sen, S. and Bains, S. S. (1951). *Indian J. agric. Sci.* 21(3)
Singleton, M. P. (1945). *Wash. Agri. Sta. Bull.* 465
Vyas, N. D. (1927). *Agri. J. India*, 22 : 180
Walker, J. E. (1931). *Agri. Livestk. India* : 59-67
West, E. S. (1938). *J. Com. Sci. Industr. Res. Austr.* 11 : 179-181

SALVAGED AMMONIUM NITRATE AS FERTILIZER

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AMMONIUM nitrate is one of the most concentrated forms of nitrogenous fertilizer containing about 34 per cent nitrogen as against 20 per cent in sulphate of ammonia. Half of the nitrogen is present in ammoniacal form and the other half in the nitrate form. The latter form is considered to be easily available to crops but the fertilizer can also meet the demand of plants which prefer to take nitrogen in the ammoniacal form. Ammonium nitrate is readily soluble in soil solution and since the whole of the material can be utilised by plants, no residue is left in the soil. Like all ammoniacals, it is acid forming in nature, but the acidity and consequent drainage of soil lime are less than that in the case of ammonium sulphate. In a series of investigations carried out by the United States Department of Agriculture [*USDA Circ. No.* 771, 1948], it was observed that on a general basis, the soil acidity developed due to the application of 40 lb. N per acre as ammonium sulphate would require 214 lb. $CaCO_3$ for neutralisation, whereas in the case of ammonium nitrate application the corresponding lime requirement would be 72 lb. only.

Extensive production of ammonium nitrate can easily be taken up by the synthetic industry. Whereas, the expansion of ammonium sulphate production is restricted due to the world-wide shortage of one of the most valuable raw materials of the industry, sulphur or its compounds, this hurdle does not come in the way of ammonium nitrate production. Any country with an organised synthetic nitrogen fixation and nitric acid industry may go in for its production as per demands.

Side by side with the stepped up production of a chemical fertilizer, it is absolutely necessary to create popularity of the material so that it may be used in more and more quantities by the crop growers. After the first world war, some industrialized countries in Europe and the U. S. A. took up large-scale experimentation on field crops with ammonium nitrate, which they have been producing in enormous quantities for defence purposes during the war days. The United States Department of Agriculture and many other European experimental centres could establish after years of investigations on several crops like wheat, corn, cotton, potato, tobacco, fruits, vegetables, etc. that ammonium nitrate is as good a source of nitrogen as other useful nitrogenous fertilizers. Gradually, the use of ammonium nitrate as fertilizer has become an established practice in the U. S. A., Canada and in some other foreign countries. A number of plants are busy in commercially synthesizing the material for fertilizer use.

Some undesirable properties of ammonium nitrate have tended to discourage its use as a fertilizer. They are its hygroscopicity, tendency to cake and hazardous nature. The U.S.D.A. and several industrial organizations have conducted

researches for the past few decades to overcome the first two impediments in the use of ammonium nitrate as fertilizer. Suitable techniques have been evolved to minimise as much as possible, these undesirable characters. The usual process followed consists of two steps : (i) granulation of the product to a round shape (which means the minimum surface area) with the elimination of most of the fine particles and suitably coating the prilled form with paraffin oil and kieselguhr to reduce tendencies of moisture absorption and caking. The coating does not, in any way, affect the fertilizing properties. The processed material is packed in multi-walled paper bags, 6 to 8 ply, lined with asphaltum between the layers, with the joints hermetically sealed. The packing is in small bags (50-100 lb. ea.) so that they can easily withstand the transit handling. Ammonium nitrate is not an explosive but being a very strong supporter of combustion, may lead to fire hazards and consequent explosion on coming in contact with readily oxidisable substances like coal, sulphur, saw dust, straw, etc. Therefore, if adequate precautions are taken in storing the sealed bags in thoroughly clean godowns in small heaps and avoiding all sources of naked flame or electric sparks and contact with readily oxidisable materials, no danger may be expected during the handling and storage of the fertilizer. Sometime back, it was felt that the material would become more hazardous under tropical climatic and storage conditions but actually several hundred tons of imported fertilizer-grade ammonium nitrate have been successfully moved during the past few months to a large number of centres, stored and used for agricultural purposes, only by observing carefully the above simple precautions.

At the end of the second world war, large amounts of ammonium nitrate usually admixtured with small amounts of T.N.T. (Tri-nitro-toluene), varying from 1 to 3 per cent, were left unused. It was desired to try the surplus material as a source of nitrogen to crops and on being approached by the Defence (then War) Department, the Indian Council of Agricultural Research requested several State (then Provincial) Agricultural Departments to undertake simple experiments to test the manurial value of salvaged ammonium nitrate, usually containing small amounts of T.N.T., on some important agricultural crops. Trials were also taken up by the Indian Agricultural Research Institute, New Delhi. The Master-General of Ordnance of the General Headquarters supplied the salvaged ammonium nitrate to all the centres of trials. The fertilizing value of ammonium nitrate was compared with other nitrogenous manures and fertilizers, organic and inorganic. Ammonium sulphate, in view of its long standing as the most important fertilizer source of nitrogen to crops, was generally included in these trials as one of the standard treatment for comparison. Field experiments were conducted on wheat, maize, paddy, cotton, *jowar* and sugarcane crops in the States of Bombay, Madras, Uttar Pradesh, Bihar, West Bengal and at the Indian Agricultural Research Institute, New Delhi.

The results of some of the agronomic experiments with salvaged ammonium nitrate, at the Indian Agricultural Research Institute and its sub-station at Karnal, have been published by Sen *et al.*, [1952]*. They have carried out field experiments for two to three years on some major field crops and have indicated that ammonium nitrate alone or admixtured with small amounts of T.N.T. was as effective as sulphate

* *Indian J. agric. Sci.*, **22**, 389, 95.

of ammonia in giving significantly higher crop yields over no manure. They also observed that the presence of small amounts of T.N.T. in the proportions of 1, 2 or 3 per cent in ammonium nitrate had no deleterious effect on the crop and the fertilizing value of the material and its presence could safely be ignored.

Having observed that the occurrence of T.N.T. upto 3 per cent in the salvaged material could be neglected for agricultural considerations, attempts have been made in this paper to consolidate the main results obtained in the experiments carried out in various parts of the country during the years 1944 to 1949 on the fertilizing value of salvaged ammonium nitrate admixtured with or without varying amounts of T.N.T. The results obtained at the Indian Agricultural Research Institute and the experimental data supplied by the Provinces (now States) have been summarized. Unfortunately, in spite of best attempts, detailed and complete information regarding all the agronomic aspects of some experiments could not be obtained and, in some cases, the statistical data were not complete. However, the yield data and other relevant details, as far as could be obtained, have been incorporated in presenting the findings. In general, the average crop yields due to treatments, have often been much higher than no manure and in many cases the results from a number of experiments carried out for more than one season, have been examined in assessing the manurial value of salvaged ammonium nitrate. The results given below are reviewed cropwise :

(a) Wheat and maize

In the year 1944-45 (*rabi*), pot culture trials to examine the manurial value of salvaged ammonium nitrate were taken up at the Indian Agricultural Research Institute, New Delhi, on wheat crop, grown in Delhi soil. Thirty pounds of air-dry soil was taken in each pot. Four replications per treatment were kept and the crop was grown to maturity. The results obtained are presented in Table I.

The results indicated that ammonium nitrate by itself proved to be an excellent fertilizer for wheat. Its manurial value was further enhanced when used along with bonemeal or rock phosphate.

Table I

Yield of wheat in pot experiments with salvaged ammonium nitrate
(Rabi 1944-45)

Treatment	Average yield of wheat (NP 165) per pot in gm.		Percentage increase in yield over no manure	
	Grain	*Bhusa*	Grain	*Bhusa*
1. No manure	4·88	9·61	..	..
2. Ammonium nitrate at 100 lb. N per acre	9·25	24·29	89·4	152·8
3. Bonemeal at 200 lb. P_2O_5 per acre	6·33	17·97	29·7	87·0
4. Rock phosphate at 200 lb. P_2O_5 per acre	5·17	9·54	5·9	..
5. Ammonium nitrate as in 2 plus bonemeal as in 3	12·21	25·63	150·2	166·7
6. Ammonium nitrate as in 2 plus rock phosphate as in 4	11·54	23·44	136·5	143·9
S.Em±	0·535	0·954	..	..
Critical difference at 5 per cent	1·59	2·83	..	..

The results of field experiments with salvaged ammonium nitrate on wheat and maize at Delhi and at some centres in Bihar are presented in Table II.

TABLE II

Results of field experiments on wheat and maize

(a) Yield of wheat (NP 165) in maunds per acre

Place	Control		Ammonium nitrate at 40 lb. N per acre	Ammonium sulphate at 40 lb. N per acre	C.D. at 5 per cent
Delhi					
Chemistry Division plots*	1944-45	14·40	29·20	..	13·30
	1945-46	9·78	22·20	..	8·51
	Mean	12·09	25·70	..	..
Institute area	1944-45	43·39	40·85	38·93	4·25
	1945-46	12·45	23·52	26·42	5·51
	Mean	27·92	32·19	32·67	..
Mean		20·00	28·95	32·67	..

* Basal dressing of superphosphate at 40 lb. P_2O_5 per acre.

(b) Yield of wheat (NP 52) in maunds per acre during 1947-49

Place	Control	Ammonium nitrate at 30 lb. N per acre	Ammonium sulphate at 30 lb. N per acre
Bihar			
Motipur	7·4	11·1	9·8
Motihari	8·2	12·1	10·9
Mean	7·8	11·6	10·4

(c) Yield of maize (Jaunpur) in maunds per acre during 1948-49

Place	Control	Ammonium nitrate at 30 lb. N/acre	Ammonium sulphate at 30 lb. N/acre
Bihar			
Pusa	6·9	9·4	8·0
Motihari	14·7	20·7	17·9
Mean	10·8	15·0	12·9

Nitrogenous treatments, in general, resulted in highly increased crop yields over no manure excepting in one trial on wheat in Delhi during 1944-45, where the crop had come up very well but due to abnormal climate lodging took place and, also, there was greater incidence of rust attack in the manured plots, which appreciably lowered the crop yields.

The no manure yield of 43 maunds of wheat per acre indicated the high fertility level of the soil and further addition of nitrogen resulted in a loss of crop.

In the Chemistry Division plots, ammonium nitrate was applied at 40 lb. N per acre over a basal dressing of superphosphate at 40 lb. P_2O_5 per acre since the soil was known to be highly deficient in phosphorus. Ammonium nitrate application increased the wheat yield to more than double in two seasons. In the trials at the Institute area during 1945-46, although the maximum yield was due to application of sulphate of ammonia at 40 lb. N per acre, the manurial value of ammonium nitrate was also of similar order.

The average of four trials at Delhi clearly indicated that salvaged ammonium nitrate could be a valuable source of nitrogen to wheat, the average increase in yield being 8·95 maunds per acre over control as compared to 12·67 maunds recorded with an equivalent dose of ammonium sulphate.

In the two wheat trials at Bihar an average increase of 3·8 maunds per acre of grain was obtained over control with 30 lb. N application as ammonium nitrate compared to 3·6 maunds increase with sulphate of ammonia.

In the two trials on maize in Bihar, each conducted for two seasons, the results were somewhat more in favour of ammonium nitrate than sulphate of ammonia, the mean increases in grain yield over control being 4·2 and 2·1 maunds per acre respectively.

In general, it will be seen from the above data that ammonium nitrate is as good as sulphate of ammonia as a source of nitrogen to cereals like wheat and maize.

(*b*) Paddy

The results of paddy trials at Karnal have been reported by Sen *et. al.*, [1952]. They observed that although during 1944-45, no increase in yield due to the application of ammonium nitrate at 40 lb. N per acre was observed, the results of 1945-46 indicated a highly significant increase in paddy yield over no manure. Both ammonium nitrate and ammonium sulphate produced similar increase in yield.

Results of a paddy experiment in the West Godavari district in Madras (composite State) are given in Table III.

TABLE III

Yield data of paddy experiment with ammonium nitrate in West Godavari districts (1945)

Treatments	Yield of paddy in md. per acre
1. No manure	20·0
2. Green leaf 4000 lb. per acre	25·3
3. Ammonium nitrate at 15 lb. N. per acre	19·7
4. Ammonium nitrate at 30 lb. N. per acre	22·5
5. Green leaf 4000 lb. plus ammonium nitrate 15 lb. N. per acre	25·7
6. Green leaf 4000 lb. plus ammonium nitrate 30 lb. N. per acre	29·4
7. Ammonium sulphate at 15 lb. N. per acre	19·6
8. Ammonium sulphate at 30 lb. N. per acre	24·1
9. Green leaf 4000 lb. plus ammonium sulphate 15 lb. N. per acre	26·5
10. Green leaf 4000 lb. plus ammonium sulphate 30 lb. N. per acre	28·9

Salvaged ammonium nitrate at 15 and 30 lb. N per acre stood at par with ammonium sulphate when used with or without a basal dressing of green leaf. For an appreciable increase in crop yield over no manure, the application of a bulky organic manure was found to be necessary in this area.

In another field trial in Chinsurah (W. Bengal), although the actual crop yields were not obtained, it was reported that the application of salvaged ammonium nitrate at 40 and 60 lb. N per acre, resulted in 18·9 and 35·1 per cent increases respectively in paddy yields over no manure. The corresponding increases with sulphate of ammonia addition were 41·2 and 58·0 per cent.

From the results of the experiments on paddy it appears that although ammonium nitrate can be a good source of nitrogen to paddy, it may not be as efficient as sulphate of ammonia. This is probably due to the fact that under wetland conditions, half of the nitrogen present in ammonium nitrate in nitrate form, gets dissipated in large bulk of water, whereas the ammoniacal nitrogen in ammonium sulphate is retained by the clay complex of the soil and is available to plants.

(c) Cotton and jowar

Results of field experiments conducted at the Indian Agricultural Research Institute Farm on cotton and *jowar* fodder during 1944-46 are given in Table IV.

Table IV

Fertilizing value of salvaged ammonium nitrate for cotton and jowar *fodder (experiments at the Indian Agricultural Research Institute, 1944-46)*

Crop	Year	Yield in md. per acre			
		No manure	Ammonium nitrate 40 lb. N/acre	Ammonium sulphate 40 lb. N/acre	C.D. at 5 per cent
Cotton	1944-45	9·11	10·33	10·20	1·15
	1945-46	9·02	12·18	11·52	1·30
	Mean	9·07	11·26	10·86	
Jowar fodder	1944-45	389·0	476·8	463·8	69·5
	1945-46	284·5	329·2	322·3	25·1
	Mean	336·8	403·0	393·0	

The experiments indicated a beneficial effect of ammonium nitrate on the yield of cotton with a slightly higher yield over the corresponding sulphate of ammonia treatment. Similar results were also observed on experiments with *jowar*. Of course, statistically, no significant difference was observed on crop yields due to the two sources of nitrogen tried.

(d) Sugarcane

Results of experiments with salvaged ammonium nitrate on sugarcane were received from Karnal (Punjab), Anakapalle (Madras) and from a number of places in Bihar and Uttar Pradesh. The experiment at Karnal was for two years and at Anakapalle for one year. Results obtained from the trials in Bihar and Uttar Pradesh were generally conducted for two to three years. The different treatments applied in these centres varied from place to place according to the local practice and convenience. In Bihar, in a few cases, two series of experiments were carried out on two varieties of cane.

Summarized results of trials on sugarcane are presented under Table V.

TABLE V

Study of fertilizing value of salvaged ammonium nitrate for sugarcane

(*a*) Yield of sugarcane in maunds per acre during 1944-46

(Basal F.Y.M. at 80 lb. N per acre)

Place		Control	Ammonium nitrate 40 lb. N per acre	Ammonium sulphate 40 lb. N per acre
Karnal	1944-45	834·7	834·9	708·3
	1945-46	835·4	951·3	962·5
Mean		835·1	893·1	835·4

Difference in yields not statistically significant.

(*b*) Yield of sugarcane in maunds per acre during 1945-46

(Nitrogen at 100 and 200 lb. per acre)

Place	Treatment	100 lb. N	200 lb. N
Anakapalle, Madras	Ammonium nitrate	1122·9	1053·4
	Ammonium sulphate	1268·3	1241·4
	Groundnut cake	1222·6	1265·9
	Groundnut cake 2/3 N + Ammonium sulphate 1/3 N.	1253·3	1249·0

'Z' test: not significant.

(*c*) Yield of sugarcane in maunds per acre during years 1945-46 to 1947-48

(N and P_2O_5 at 40 lb. and 50 lb. per acre respectively)

Place	Control		Castor cake + Triple super		Ammonium phosphate + Ammonium sulphate		Ammonium nitrate + Triple super		C.D. at 5 per cent
Bihar	Co. 313	Co. 513	Co. 313	Co. 513	Co. 313	Co. 513	Co. 313	Co. 513	
Pusa	319·7	284·5	279·2	411·8	352·9	352·3	331·4	305·3	not sign.
Harinagar	483·4	..	546·9	..	511·5	..	585·1	..	73·8
Motihari	606·4	..	637·6	..	605·9	..	642·1	..	not sign.
Mean	469·8	..	487·9	..	490·1	..	519·5	..	

(*d*) Yield of sugarcane in maunds per acre
(N and P_2O_5 at 60 lb. and 30 lb. per acre respectively)

Place and Year	Control		Castor cake + Triple super		Ammonium phosphate + Ammonium sulphate		Ammonium nitrate + Triple super		C.D. at 5 per cent
Bihar	Co. 313	Co. 453	Co. 313	Co. 453	Co. 313	Co. 453	Co. 313	Co. 453	
Patna 1945-46	358·1	371·0*	426·8	479·0*	542·3	475·4*	484·6	426·2*	Co. 313 108·6
Dehri 1947-48	..	442	..	504	..	508	..	544	Co. 453,93 49·5
Bikramganj 1947-49	..	398	..	451	..	476	..	514	98
Mean	..	403·7	..	488·0	..	486·5	..	494·7	..

* At Patna, means for Co. 453 are based on yield figures for years 1945-46 to 1947-48

(*e*) Yield of sugarcane in maunds per acre of the variety Co. 313
(N at 60 lb. per acre)

Place and Year	Control	Castor cake	Ammonium sulphate	Ammonium nitrate
Bihar				
Sabour 1945-47	334·9	337·0	407·2	402·2

Differences not significant

Uttar Pradesh

(*f*) Yield of cane in mounds per acre

Quality	Levels of N in lb. per acre				Mean
	Muzaffarnagar (1945-46 to 1248-49)				
	0	60	120		
Ammonium sulphate	576	716	841		778·5
Ammonium nitrate		721	814		767·5
	(*g*) Shahjahanpur (1945-46)				
	0	60	100		
Ammonium sulphate	271·5	393·1	462·9		428·0
Ammonium nitrate		436·0	560·9		498·5
	(*h*) Gorakhpur (1946-47 to 1948-49)				
	0	60	100	180	
Ammonium sulphate	363	432	472	464	456
Ammonium nitrate		417	411	426	418

Experiments carried out at Karnal on sugarcane did not indicate any beneficial effect due to nitrogen fertilization in the first year, but during next year both ammonium nitrate and ammonium sulphate application produced 116 and 127 maunds of extra cane per acre respectively. The increase in yield was, however, not statistically significant. It appears that the effect of the fertilizer treatments could not come up over a heavy basal dose of farmyard manure.

In the one year trial at Anakapalle, a comparison was made between the different sources of nitrogen—organic, inorganic and mixed. The differences in cane yields were not statistically significant, showing that the different treatments behaved more or less similarly, ammonium nitrate giving somewhat lower yield than others.

Trials in Bihar were carried out at Pusa, Harinagar and Motihari in North Bihar, and at Patna, Dehri, Bikramganj and Sabour in South Bihar. The cane of variety Co. 313 was planted in all the North Bihar centres and in addition, Co. 513 was grown at Pusa. In South Bihar, the variety Co. 313 was grown at Patna and Sabour and Co. 453 at Patna, Dehri and Bikramganj. Centres in the north received a treatment of 40 lb. N and 50 lb. P_2O_5 per acre, while those in the south received 60 lb. N and 30 lb. P_2O_5.

At Pusa, ammonium nitrate gave higher cane yields over no manure with both the varieties but the differences were not statistically significant. Similar results were also reported from Motihari in a three-year trial where although ammonium nitrate produced the maximum yield, the increase over control was not statistically significant. At Harinagar, however, the average yield of three years indicated a significant increase in cane yield over no manure when ammonium nitrate was applied with triple superphosphate whereas oilcakes with triple super or ammonium sulphate plus ammonium phosphate treatments were ineffective.

In South Bihar trials, at Patna, the increase in yield due to ammonium nitrate plus triple super was significant with both the Co. varieties 313 and 453, the extra cane produced per acre over control being 126·5 and 55·2 maunds respectively. The yields were, of course, slightly lower than those obtained with a mixture of ammonium sulphate and phosphate. At Dehri, only ammonium nitrate gave significant increase in yield, whereas other manure mixtures failed to do so. Similarly, at Bikramganj only ammonium nitrate with triple super producing 116 maunds of extra cane per acre over control showed a significant rise, other differences being not significant. At Sabour, although single application of ammonium nitrate at 60 lb. N per acre produced 67·3 maunds of extra cane over control as compared to 72·3 maunds with sulphate of ammonia, the differences were not significant.

In Uttar Pradesh, in the three-year trial at Muzaffarnagar, both ammonium nitrate and ammonium sulphate giving high increases in cane yields over no manure (191·5 and 202·5 maunds per acre respectively), were found to be of equal merit. The yields were considerably higher when the N level was raised from 60 to 120 lb. per acre. In an one-year experiment at Shahjahanpur, both the sources of nitrogen produced much higher yields : ammonium nitrate was somewhat better than ammonium sulphate, the mean increases in yields over no manure being 227·0 and 156·5 maunds per acre respectively. At Gorakhpur, the results for two years showed

that whereas ammonium sulphate, applied at 60, 100 and 180 lb. N per acre increased the cane yield over control by 93 maunds per acre the mean increase due to corresponding doses of ammonium nitrate was 55 maunds only.

From the results of the number of trials carried out for one to three years in Karnal, Madras, Bihar and Uttar Pradesh it may be concluded that salvaged ammonium nitrate proved as good as ammonium sulphate as a valuable source of nitrogen to sugarcane, and in some cases it was even better.

In the light of the above findings, it may be stated that salvaged ammonium nitrate would be a highly suitable nitrogenous fertilizer for crops of short duration like wheat, maize, cotton and *jowar* and as good as sulphate of ammonia on equivalent nitrogen basis. For paddy crop, ammonium sulphate was somewhat superior to ammonium nitrate. For a long duration crop like sugarcane, with which a number of trials were carried out in different centres, the behaviour of ammonium nitrate was as good as sulphate of ammonia in most cases and in few instances it proved even slightly superior to ammonium sulphate.

Summary

In this paper, the results of a large number of trials on different important agricultural crops carried out during 1944-49 in various parts of India with salvaged ammonium nitrate, a highly concentrated nitrogenous fertilizer containing 34 per cent nitrogen, have been reviewed and summarized, with a view to ascertaining its manurial value. It has been observed that

1. Ammonium nitrate is an excellent nitrogenous fertilizer for short duration crops like wheat, maize, *jowar*, etc. and is fully comparable to ammonium sulphate, but for paddy the latter seems to be somewhat better.

2. For a long duration crop like sugarcane it can be placed on equal merit with sulphate of ammonia.

3. The presence of T. N. T. upto 3 per cent in the material could be ignored in judging its manurial value.

4. Ammonium nitrate is, no doubt, highly hygroscopic and hazardous but can be conveniently handled without any danger by following proper handling procedures and precautions.

Acknowledgment

Besides the results of the experiments carried out by the authors, other data used in the preparation of this paper were very kindly supplied by Shri K. L. Khanna, Director of Sugarcane Research and Development, Bihar, and Dr B. K. Mukherjee, Additional Director of Agriculture, Uttar Pradesh and also by other officers from the States. Thanks are due to all the above officers and also to Mr. C. H. Parr, the then Imperial Agriculturist and Dr S. V. Desai, the then Soil Microbiologist of this Institute, for their helpful advice in taking up the problem for investigations.

STUDIES ON THE VARIATIONS IN PHYSICAL PROPERTIES OF CLAYS AND SOIL DURING HYDRATION AND HUMIFICATION

A COMPARATIVE STUDY ON THE VARIATIONS IN pH AND CONDUCTIVITY OF CLAYS AND AGRA SOIL UNDER LABORATORY CONDITIONS

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(With two text-figures)

In continuation of our previous publication [Bansal and Bhattacharya, 1952] relating to the studies on the variations in pH and conductivity during hydration and humification of clays and Agra soil under natural conditions, we have further extended our observations on the variations of pH and conductivity under laboratory conditions. Variations obtained by adding different kinds of leaves, cowdung and oilcake as humifying agents have been comparatively studied and the results presented in this article.

Experimental

The experimental procedure and the technique were identical with those adopted for studying the pH and conductivity values under the natural conditions (*loc. cit.*). The clays and the sample of Agra soil were analysed quantitatively by the standard methods given by Cumming and Kay [1928] and Piper [1947] and were then mixed with raw organic matter in the ratio of 8 parts of clay or soil to 3 parts of organic matter ; one litre of water was then poured (i.e. the mixture contained 800 grams of soil or clay, 300 grams of raw organic matter and one litre of water). The ingredients of each trough were thoroughly mixed. The mixture was allowed to hydrate and humify and the changes in pH and conductivity were determined every fortnight by the same method described in previous paper (*loc. cit.*). Water level was maintained in each trough up to the same level throughout the period of investigation. The results of analyses of clays and Agra soil are given in Table I based on the average of three estimations.

Table I

Results of analyses of Simultala, Rajmahal and Kasim Bazar clays and Agra soil

Constituent in per cent	Simultala	Rajmahal	Kasim Bazar	Agra soil
SiO_2	44·40	55·13	52·49	84·19
Fe+Al oxides	42·35	35·02	35·73	7·190
CaO	0·76	0·61	1·47	1·55
MgO	0·26	0·20	0·57	1·021
Loss on ignition	12·14	9·24	9·24	5·10
Total	99·91	100·20	99·50	99·05

Discussion

From Fig. 1 and 2 showing the relative changes in pH and conductivity the following observations are interesting.

1. Alkalinity of clays and soil is increased by hydration and humification with cowdung and leaves.
2. With dry *peepal* leaves the conductivity of the humified clays and soil is less than that with cowdung. More alkalinity is produced with *peepal* leaves than that with cowdung.
3. With green *neem* leaves greater conductivity but less alkalinity is produced as compared to *peepal* leaves.
4. With cauliflower, spinach and *murena* leaves, the tendency towards alkalinity is slightly more marked than in the case of *peepal* leaves or cowdung.
5. Oilcake shows the greatest conductivity compared to the leaves and cowdung. In the earlier stages of humification of clays and Agra soil, the oilcake produces appreciable acidity but in the later stages (four months) they tend to become alkaline.

The leaves in cowdung have been found to increase the pH of clays and Agra soil for a considerable period. It will be seen from the curves that the maximum change in pH during the last stages of humification is observed with cauliflower, spinach and *murena* leaves. The oilcake shows appreciable fall in pH in the early stages after which a gradual increase is observed. The practical importance that follows from these observations is that the sourness in the soil may be controlled by the humification of suitable raw organic matter such as the leaves mentioned above to make the soil more conducive to plant growth. In the same way, the alkalinity of the soil may be reduced by the humification of oilcake according to our observations. It may be further observed that suitable manures or composts having different pH values can be prepared by using different raw organic matter. Hence it appears possible to maintain the optimum pH in the soil required for the growth of a particular crop by using such manures as would render an effective control over the pH of soil.

From the graphs (Fig. 1 and 2) it can be generalised that the changes of pH and conductivity during the humification of the clays and the soil brought about by different kinds of leaves, cowdung and oilcake are periodic in nature. There is an appreciable similarity in the periodicity of the variation when the humification is carried out under natural and laboratory conditions as has been published in our previous publication (*loc. cit.*). Although the mechanism of humification is apparently similar as evidenced by the variations of pH and conductivity, the fact remains that these changes take place in a very complicated manner depending upon ; (i) the hydrolytic ratios of the alkaline earths, iron and aluminium contents [Spurway, 1917] ; (ii) hydrolysis of silicates and organic matter, and the formation of complexes of organic matter with bases [Noyes, 1919] and (iii) the absorption of bases and acids by the soil colloids [Mukherjee, 1922 ; Kiuhei and Kobayashi, 1920 ; Osugi Netsuki, 1916].

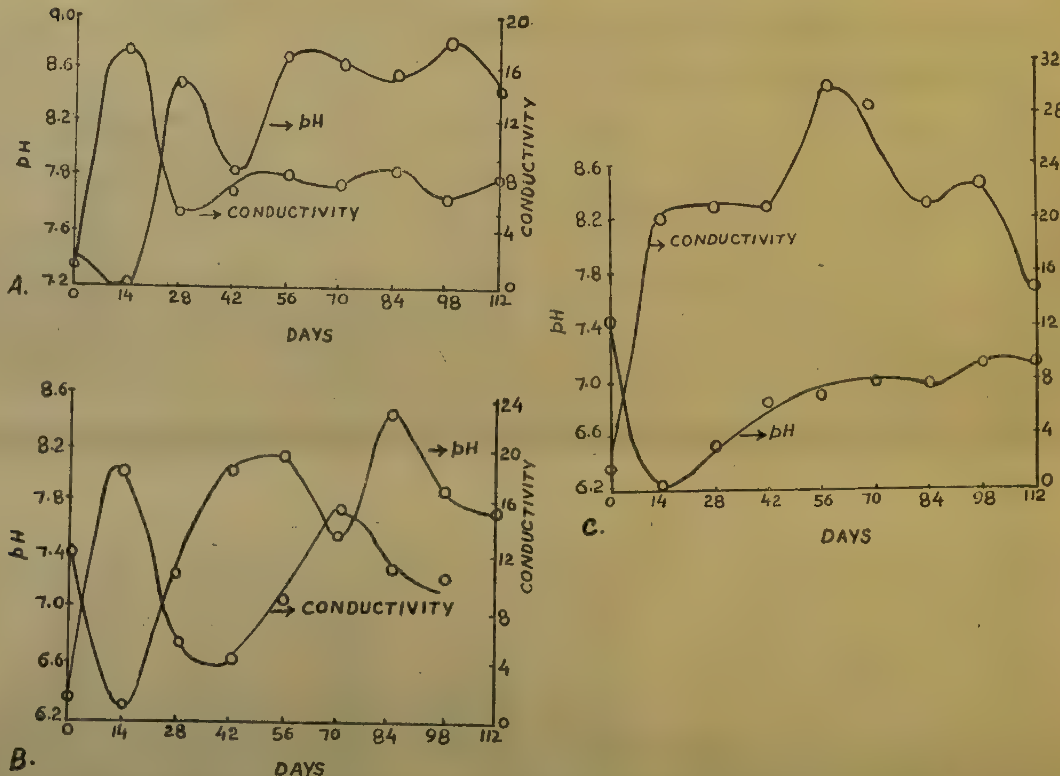

FIG. 1—(Top left) Humification with spinach leaves. (Bottom left) Humification with murena leaves. (Right) Humification with oil cake. The curves show the relation between (i) time and pH, and (ii) time and conductivity. These curves represent Rajmahal clay.

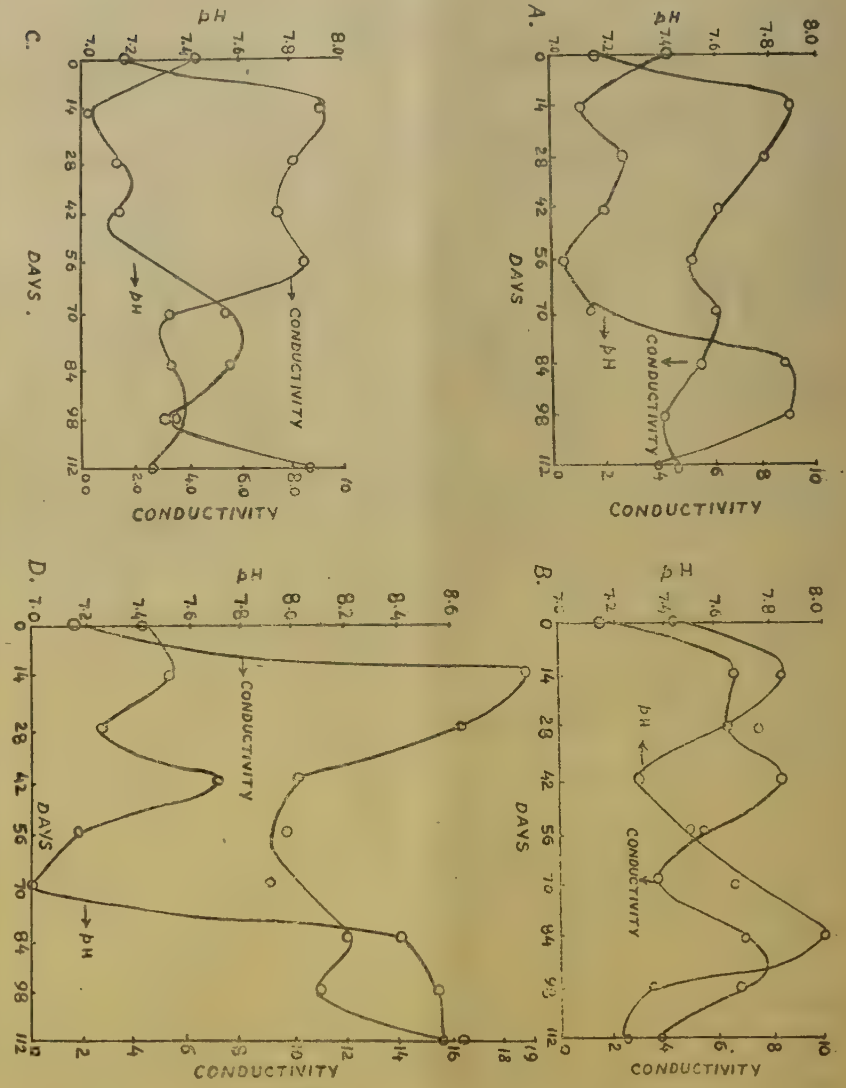

FIG. 1-A—Humification with cow-dung. B—Humification with *peepal* leaves. C—Humification with *neem* leaves. D—Humification with cauliflower leaves.

Summary

The changes in pH and conductivity of three different types of clays (Rajamahal, Kasim Bazar and Simultala) and Agra soil during their humification with different leaves, cow dung and oilcake have been studied under laboratory conditions and the results have been compared. While the leaves of cauliflower, *murena* and spinach produced a greater tendency towards alkalinity than *peepal* leaves and cow dung, the effect of adding oilcake was to develop appreciable acidity in the earlier stages of humification. Green *neem* leaves produced greater conductivity but less alkalinity than the *peepal* leaves. The chemical action of all the organics was found to be specific.

The variations of pH and conductivity were found to be periodic during humification both under natural and laboratory conditions. The mechanism of humification with different raw organic matter appears to be similar but not identical.

Acknowledgement

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REFERENCES

Bansal, O. P. and Bhattacharya, A. K. (1952). *J. Indian Chem. Soc., Industry & News Ed.,* **15**, **30**

Cumming and Kay (1928). *A text-book of quantitative chemical analysis*, 253

Kiuhei and Kobayashi (1920) *J. Chem. Industr.* Japan, **23**, 549-55

Mukherjee, J. N. (1922). *Nature* **110**, 732

Noyes, H. A. (1919). *J. Industr. and Eng. Chem.* **11**, 1040-49

Osugi, S. and Netsuki, T. (1916). *Ber. Ohara Inst. Landw. Forest,* **1**, 27-52

Piper, C. S. (1947). *Soil and plant analysis*, 139

Spurway, C. H. (1917). *J. Agric. Res.* **11**, 659-72

GREEN MANURING WITH SPECIAL REFERENCE TO *SESBANIA ACULEATA* FOR TREATMENT OF ALKALINE SOILS

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(With Plates VIII—X and seven text figures)

During the course of soil survey of Karnal District (Fig. 1), it was revealed that considerable area of land was lying waste on account of the presence of salts of carbonates and bi-carbonates of sodium, commonly known as black alkali soils. In the Punjab (undivided), black alkali soils did not exist and there was no occasion to take up the reclamation of sodium carbonate soils. After partition of the Punjab and with the commencement of the 'Grow More Food' campaign in the country on a nation-wide scale, it became imperative to tackle such lands and bring every possible area under the plough. For the reclamation of sodium carbonate and bi-carbonate soil, work was started on a semi-field scale in the Research Institute and on a field scale in the Karnal district, at Indri and Nissang Reclamation Farms. These black alkali soils have a *p*H value of 8·5—10·0 and are hard, impervious, toxic to plant life and deflocculate when they come in contact with water. Most of the plant nutrients like phosphates, iron, zinc and manganese become unavailable to the plant at high *p*H values.

To improve such deteriorated soils, organic and inorganic chemicals were tried. Although some of the chemicals like sulphuric acid, sulphur, calcium chloride, gypsum, press mud, molasses and distillery waste, farmyard manure, etc. were successful to a sufficient degree, yet the cost of treatment worked out to be heavy. The distillery waste and press mud are waste products, but these too have limitation and can only be used in the vicinity of distilleries and sugar factories. The results of these experiments showed that unless some economic substitute was found, these chemicals, due to cost and non-availability, may not find favour with *zamindars*. Naturally the choice fell on some crop which could grow and be utilized as green manure and could open the soil with its extensive root system, reduce the *p*H value and improve the soil tilth. Of course, to establish the green manuring crops in highly alkaline and saline soils, leaching has to be done to wash down the very high percentage of salts. Before giving an account of the green manuring work, it is necessary to make a brief mention of the necessity of manuring and the general soil manures, both organic and inroganic.

Manuring of soils

By continuous cultivation and without any recoupment, the soil is deprived of its nutrients which are essential for good yields. The soil acts as a store house for plant food and this store is by no means inexhaustible. To maintain the fertility of the soil, it is essential that the lost nutrients must be replenished by artificial means to get normal yields. This method of replenishment is called manuring.

Fig. 1.—Irrigation Research Institute, Punjab. Karnal Soil Survey.

Types of manures

Manures are of two types, organic and inorganic. The chief organic manures are farmyard manure, night soil, compost, green manure, oilcakes, urea, bone meal, blood, etc. The inorganic manures are ammonium nitrate, nitro chalk, muriate of potash, ammonium sulphate, nitrate of soda, superphosphate, potassium nitrate etc.

In India due to financial condition inorganic manures are not within the means of an average cultivator. The use of these manures has, therefore, not become popular so far due to high prices.

As regards organic manures, farmyard manure is mostly used, but this is not available in sufficient quantity. A farmer with a holding of 25 acres and having about eight head of cattle can hardly produce about 40 tons of manure which, combined with sweeping, shall suffice only for four to five acres of land. On this basis each field can receive manure only once in five to six years. This shall be so when the *zamindar* does not use dung as fuel, but in practice a major portion of dung is used as fuel. The other organic manures like bonemeals, oilcakes, etc. are expensive. Also in view of the comparative low yield in India manuring is very essential.

TABLE I

Average outturn of wheat and rice per acre

Countries	Wheat lb.	Rice lb.
India	700	750
Egypt	1,918	2,988
Japan	1,713	3,444
China	1,898	2,433
U.S.A.	..	2,185

Green manuring

To make up the shortage of farmyard manure, choice naturally falls on a green manure crop which a cultivator can produce in his own land and with his own labour.

The use of green manure increases the water holding capacity of sandy soil, improves the tilth of clayey soil by opening it, increases the aeration, facilitates drainage and requires less water for crops. It creates crumb structure in the soil which is most important from agricultural point of view. It increases the organic matter content and the nitrogen content of the available nitrogen in the soil, it reduces the loss of mineral nitrogen by leaching, decreases the alkalinity of the alkaline soil and it may also concentrate nutrients likely to be deficient in the surface soil and leaves them there in readily available form.

Green manuring crops

The green manuring crops are of two types, non-leguminous and leguminous. The non-leguminous crops provide only organic matter while leguminous crops like berseem, *methra*, sannhemp, *guara* and *jantar* make available both organic matter as well as nitrogen. Leguminous crops have nodules of bacteria on their roots which directly take nitrogen from the air and fix it into the soil.

The common green manure crops used in the Punjab are sannhemp (*Crotalaria juncea*) and *guara* (*Gyamopsis psoraloids*). Sannhemp is preferred in sub-mountainous tracts such as Gurdaspur and Hoshiarpur districts of the Punjab, as *guara* does not flourish there. *Guara* is mostly used in the canal irrigated tracts of Amritsar, Ambala, Ludhiana and Jullundur districts.

Another green manure locally known as *jantar* or *dhaincha* (*Sesbania aculeata*) is tried for green manuring of rice in *kharif* in the reclamation rotations. A decade back *jantar* as green manure was not known as is evident from the text-books of agriculture, where only *guara* and sannhemp as green manures have been advocated.

Jantar was first cultivated in the Punjab in 1941 at the Thal Experimental Farms and then on a larger scale in 1943-44 at the Reclamation Farms at Chakan-wali and Haveli in the Punjab (Pakistan). Now this is regarded to be a very good green manuring crop both for alkaline as well as for normal soils. Field photos of the three green manuring crops *jantar*, *guara* and sannhemp are given in Plates VIII and IX.

Experiments with guara, *san-hemp and* jantar

The investigation at Amritsar was started about two years back in association with Dr C. L. Dhawan and Shri M. M. L. Malhotra in the Research Institute on the following lines :

1. Adaptability of crop under field conditions, in alkaline soils.
2. Amount of green matter produced.
3. Amount of nitrogen produced.
4. Effect on the reduction of alkalinity.
5. Effect on yield of the succeeding crops.
6. Effect of burying on large scale at different depths.

Experiments were undertaken in the field under actual saline and alkaline conditions at the Indri and Nissang Experimental Farm under the supervision of Shri U. S. Dalal. The work is being continued. A reference to some of the results obtained is given below :

1. *Adaptability of crop for green manuring*

Out of three green manures tried, only *jantar* has been able to establish in soils having high *p*H values. In soils where *p*H and salt content are high, leaching is necessary before the seeds can germinate and establish. It has been observed that where rice fails, *jantar* is able to establish. *Jantar* when transplanted can stand *p*H above 9·5 and this method of establishing the plant in highly alkaline soils can be practised with advantage.

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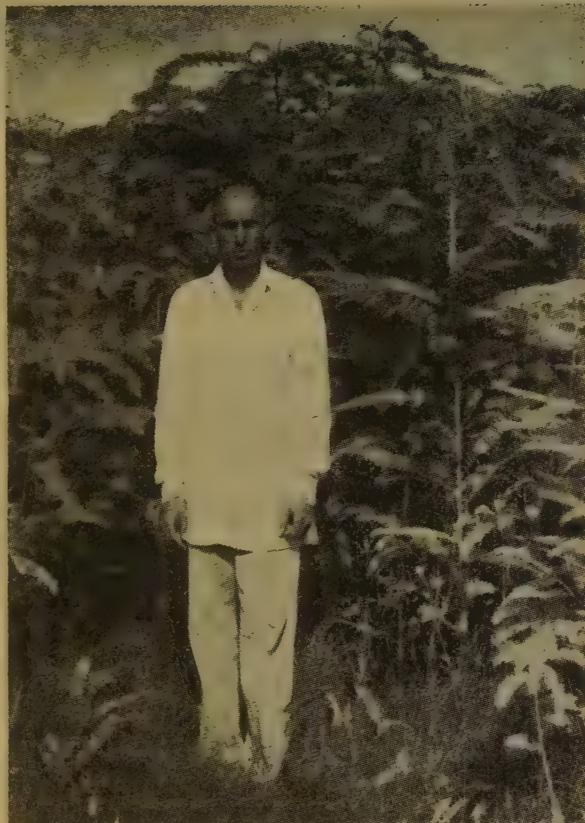


A. *Jantar* about two and a half months old

B. *Jantar* about four months old

C. *Guara*

D. Sannhemp

2. *Amount of green matter produced*

The plant which will give the maximum amount of green matter both in normal and deteriorated soils is of greater value than the crop with less total outturn of green matter per acre. It has been seen that *jantar* invariably gives double the yield than that of *guara* and sannhemp in alkaline as well as in normal types of soil.

Name of crop	Yield of green manure
San-hemp	200 md. per acre
Guara	225 md. per acre
Jantar	400 md. pr acre

3. *Amount of nitrogen produced*

(*a*) Nitrogen percentage on oven-dried weight of different green manure crops was determined. Results obtained are given Table II.

TABLE II

Percentage of nitrogen in oven-dried stem and leaves of green manure crops

Name of crop	After one month of sowing		
	Nitrogen in stem	Nitrogen in leaves	Plant as a whole
Sannhemp	1·236	4·508	2·014
Guara	1·548	4·802	3·182
Jantar	1·162	4·928	2·863

Guara gives greater percentage of nitrogen. However, since the yield of green matter in the case of *jantar* is at least double that of *guara*, the total nitrogen percentage in *jantar* will be more.

(*b*) The fresh roots of the plants were analysed for nitrogen content and the following results were obtained :

Jantar root	0·349 per cent
Guara root	0·3305 ,,
San root	0·3092 ,,

4. *Effect on increase of nitrogen content in the soil*

The samples of the root soil were examined to find out the increase in nitrogen content brought about in the soil by the nitrogen fixing bacteria on the nodules of the plant roots and the following results were obtained :

	Per cent
Jantar root soil	·0980
Guara root soil	·0805
San root soil	·0770
Control	·0595

5. *Effect on reduction of alkalinity*

To investigate the effect on reduction of alkalinity an experiment was conducted by taking out juice from the leaves of all the three green manures when they were six weeks old. *p*H values were determined when the juices were one day, 6 days, 18 days, 26 days, 35 days, 44 days, 56 days, 76 days, 81 days, 91 days, and 113 days old. The results are given in Figure 2. From this figure it is clear that *jantar* retained *p*H values below 7, i.e. below neutral for about 75 days, in the case of sannhemp for 35 days and in the case of *guara* for 30 days, which shows the strength of acid present in different green manures. In the case of *jantar*, the initial *p*H values of juice was 4·01 while in the case of sannhemp and *guara* it was above 5. The rise of *p*H value in *jantar* was very slow for the first 30 days, while it shot up in the case of *guara* and sannhemp within the first six days. The investigation is still being carried out, but it can be safely inferred that when buried *jantar* will play much greater role in the reduction of alkalinity as compared to other green manure crops. Similarly results obtained for the second year for stem, leaves and combined stem and leave juices are given in Figs. 3a, 3b, 3c, 4a, 4b, 4c and 5a, 5b, 5c.

6. *Effect on yield*

As already mentioned *guara* and sannhemp were not able to establish in sodium carbonate soils. *Jantar* did establish and was green manured. The increase in yield over the controlled plots is evident from Table III.

TABLE III

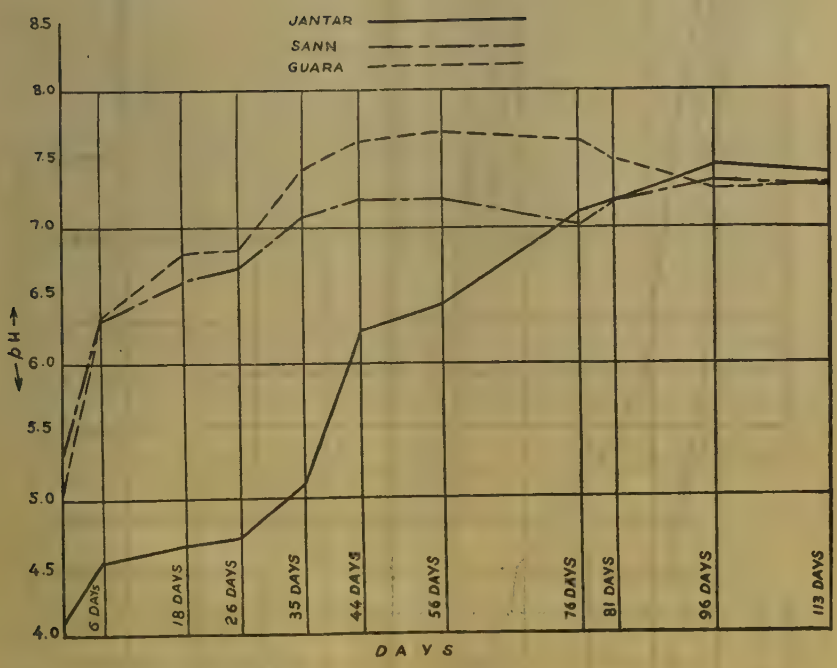
Increase in yield over controlled plots

Year	Crop	Yield per acre from controlled plots		Yield per acre from green manured plots	
		Md.	Seer	Md.	Seer
Kharif 52	Rice	13	6	38	31
Rabi 52	Berseem	740	..	807	20
	Fodder	..	..	..	..
Kharif 53	Rice	54	..	54	10
Rabi 53-54	Berseem	656	..	749	..
	Fodder	..	..	..	..

In order to verify these results, large-scale tests were conducted in the field with different types of soils. Both the water-logged and saline as well as alkaline and highly impermeable soils were selected for the tests. The experiments with *jantar* on the water-logged and saline soils were carried out at the Indri Reclamation Farm of the Irrigation Research Institute. This farm which occupies an area of 1,000 acres is representative of badly water-logged, infested with *dab* and wild dates and highly saline tract (Plate X, Fig. E) lying along the Western Jamuna Canal.

E. A view of a part of the Indri Farm. It is on this type of land infested with *dab*, and wild dates that *jantar* green manuring was tried with success.

F. A view of the part of Nissang Reclamation Farm. It is on this type of hard impervious alkaline land that green manuring with *Jantar* was tried with success.



Date of sowing : 1-7-53
Date of extract : 14-8-53

FIG. 2.—pH of leaf juice of each green manure on different days.

Date of sowing : 22-3-54
Date of extract : 6-5-54

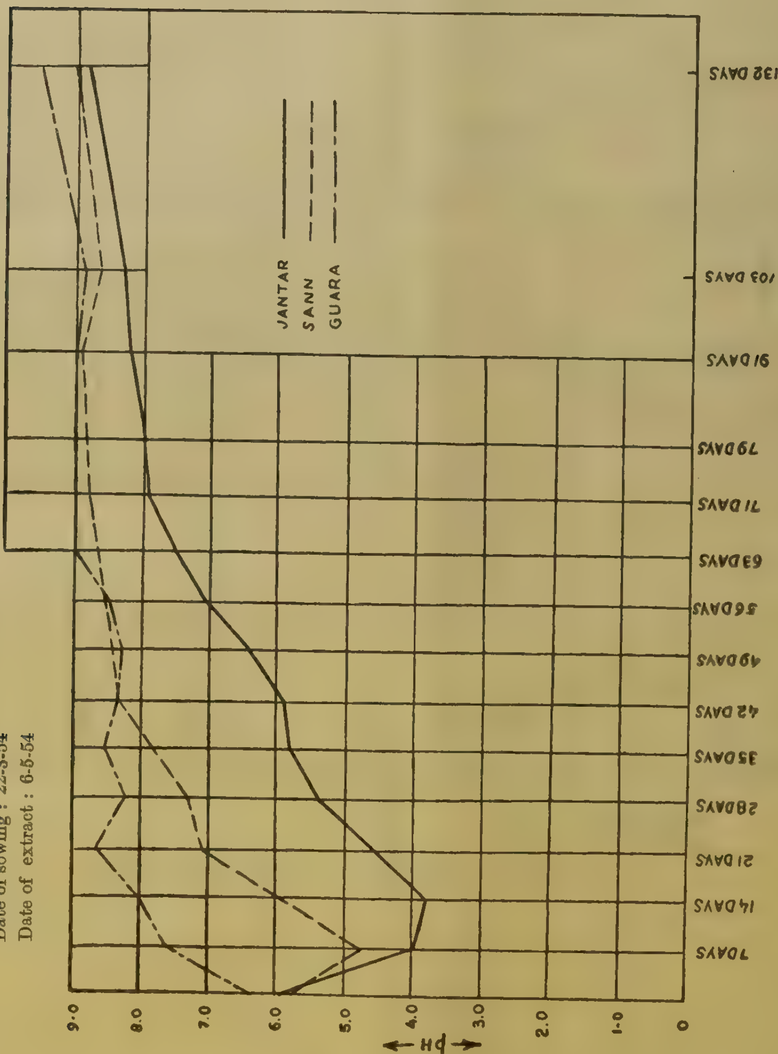


Fig. 3(a).—Variation in pH of Stem juices of different green manures.

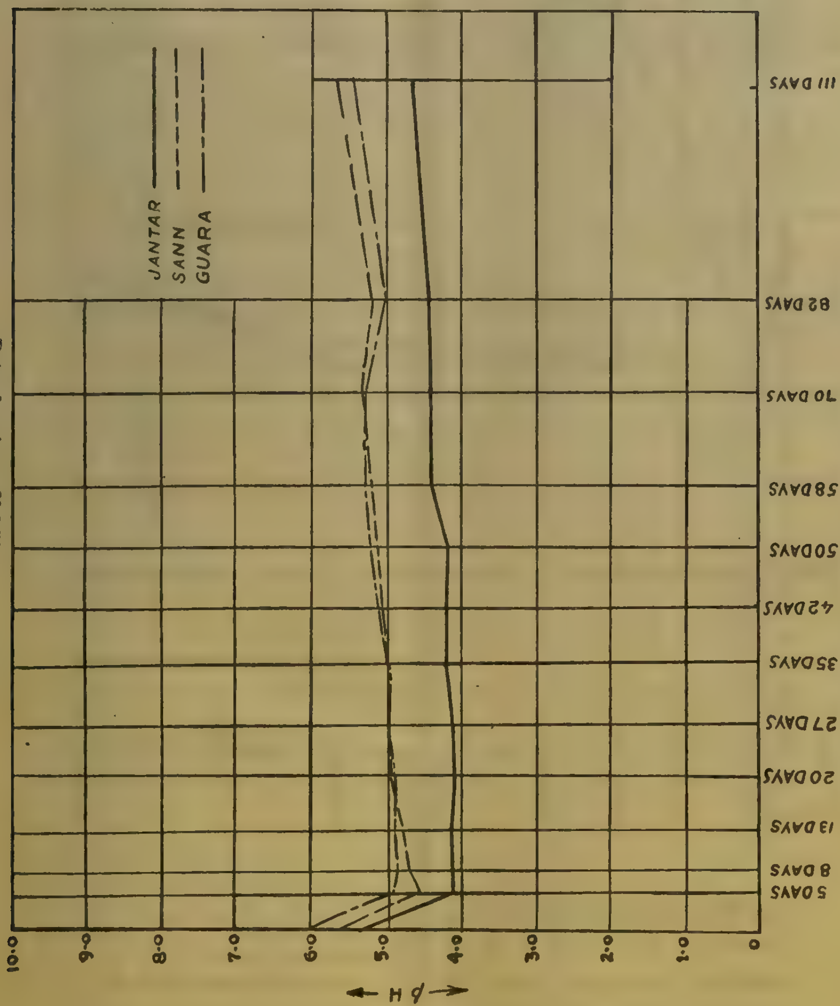


Fig. 3 (b). Variation in pH of stem juices of different green manures.

Date of sowing : 29.3.54
Date of extract : 29.5.54

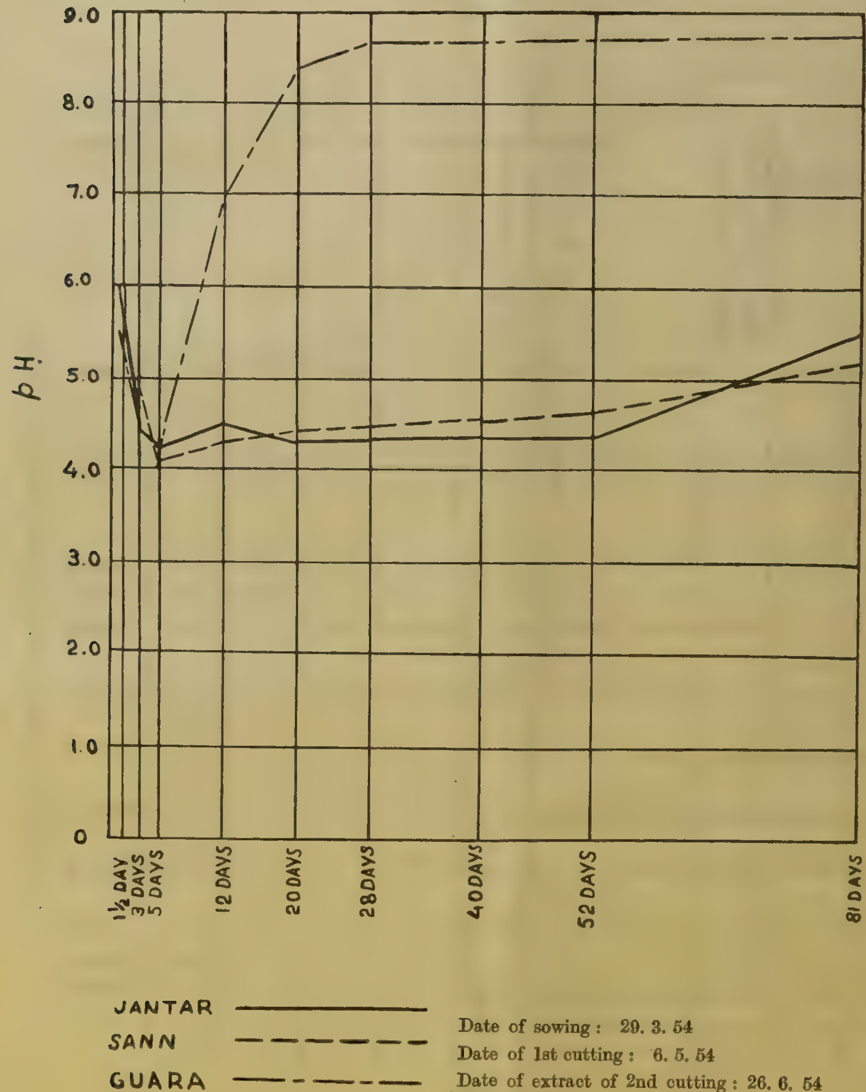


FIG. 3 (c). Variation in pH of stem juices of different green manures.

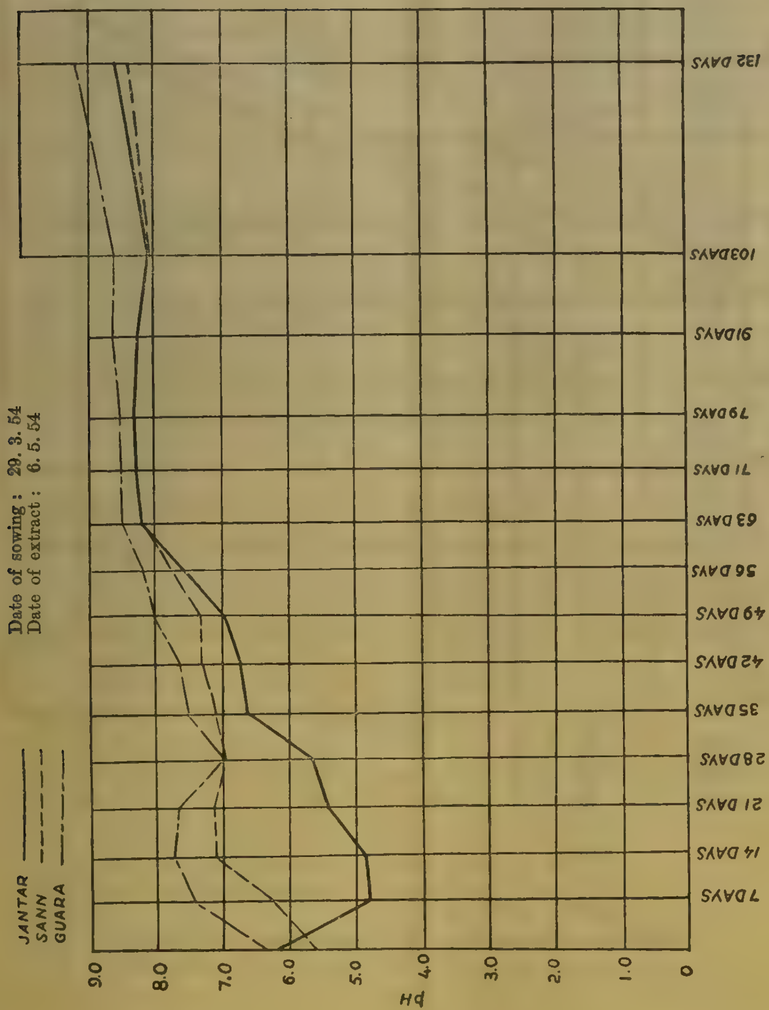


Fig. 4 (a). Variation in *p*H of leaf juices of different green manures.

10 A

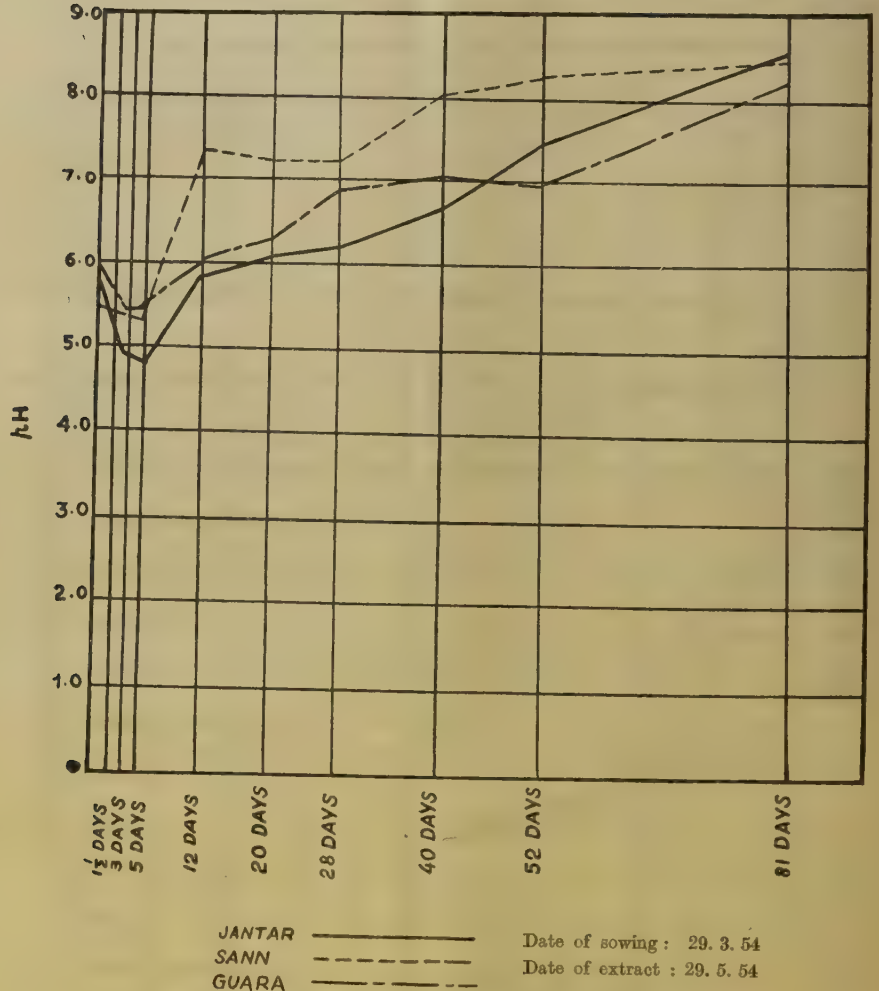


FIG. 4 (b). Variation in pH of leaf juices of different green manures.

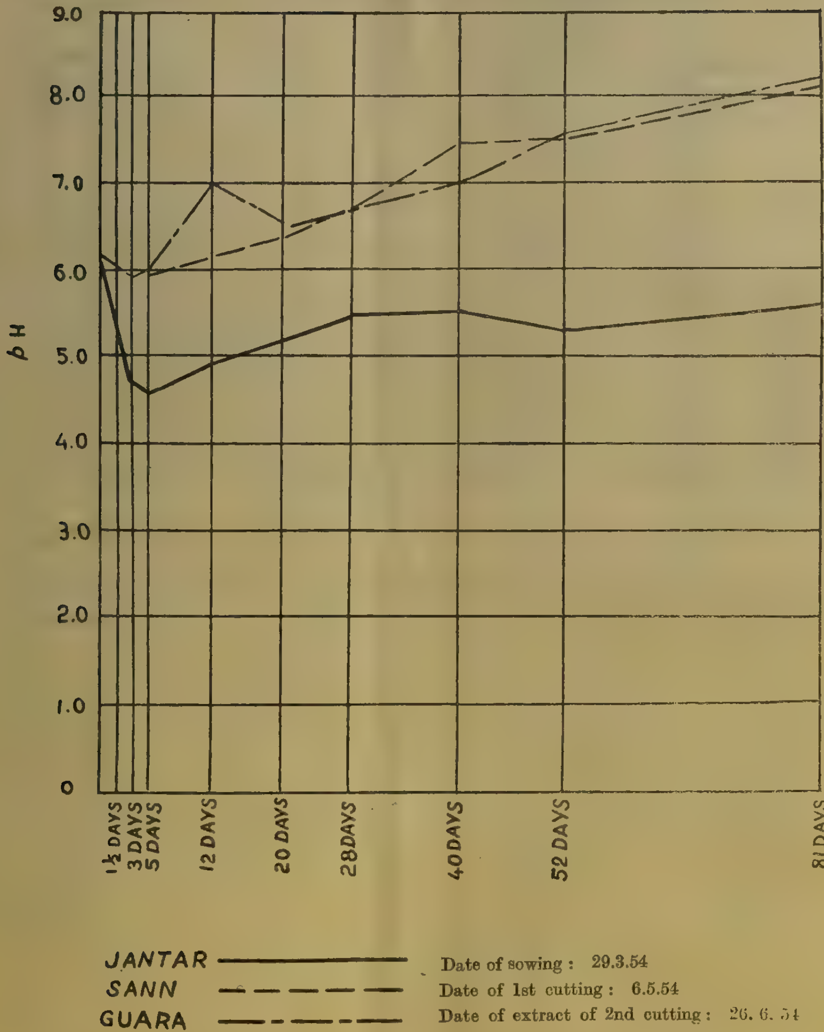


Fig. 4 (c). Variation in pH of leaf juices of different green manures.

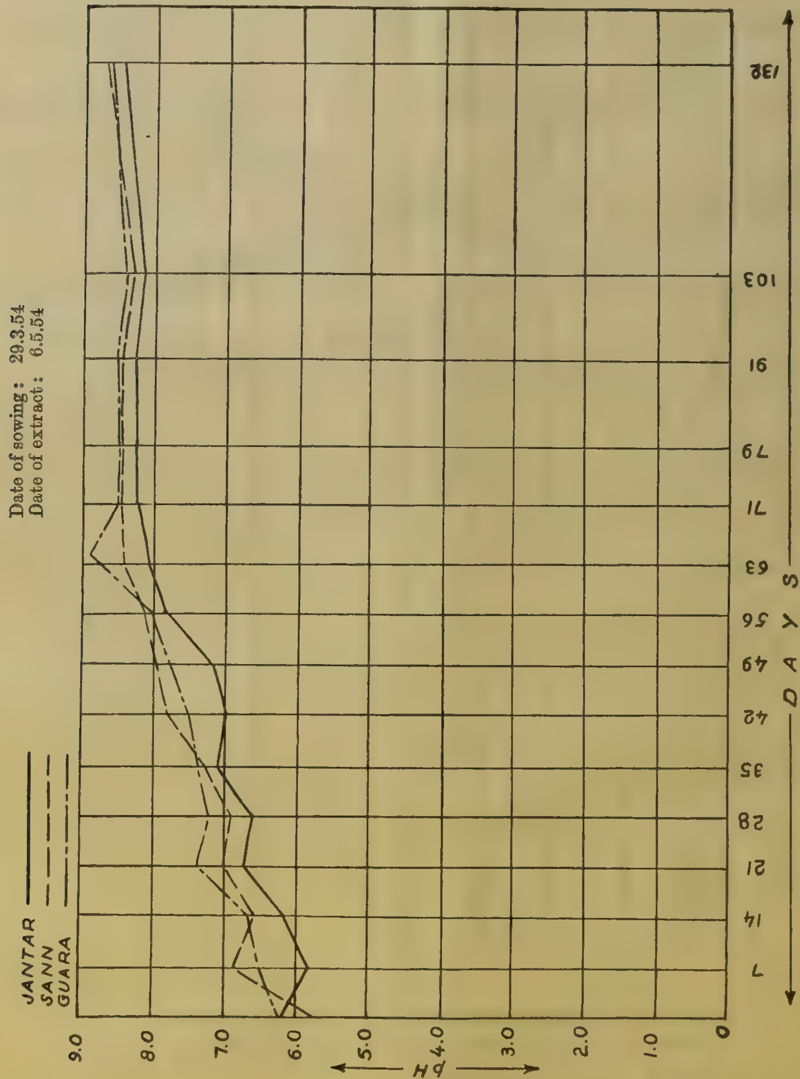


Fig. 5 (a). Variation in pH of leaf and stem juices combined in different green manures.

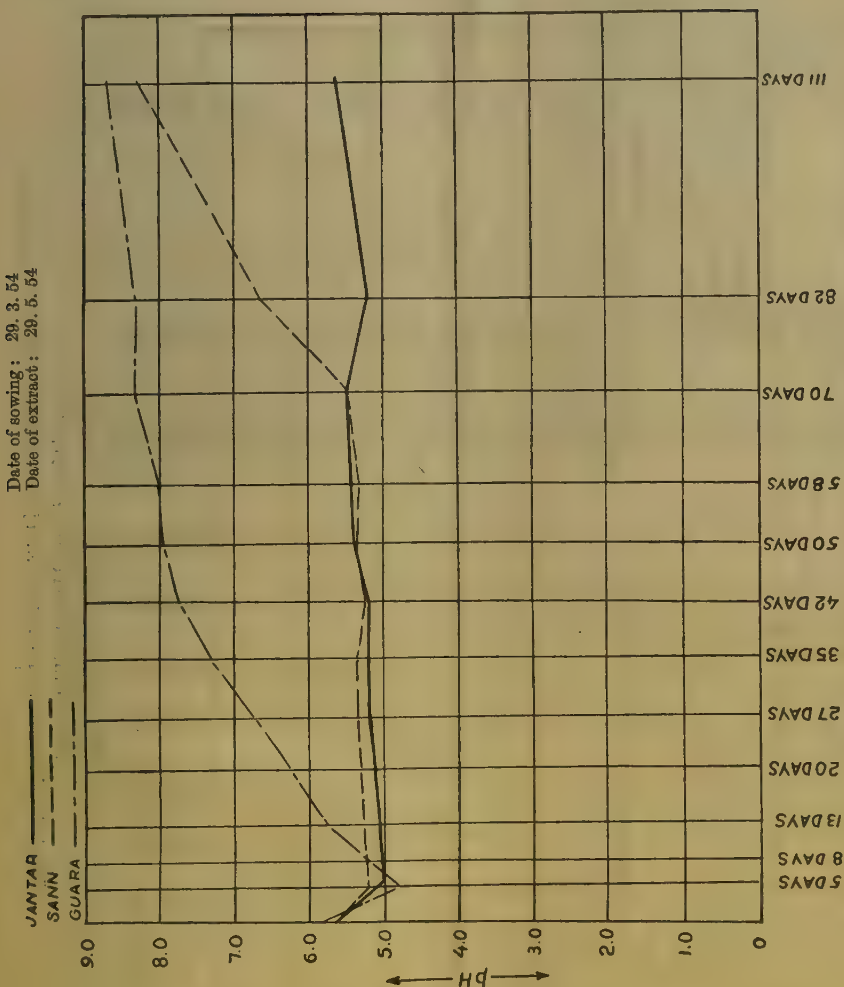
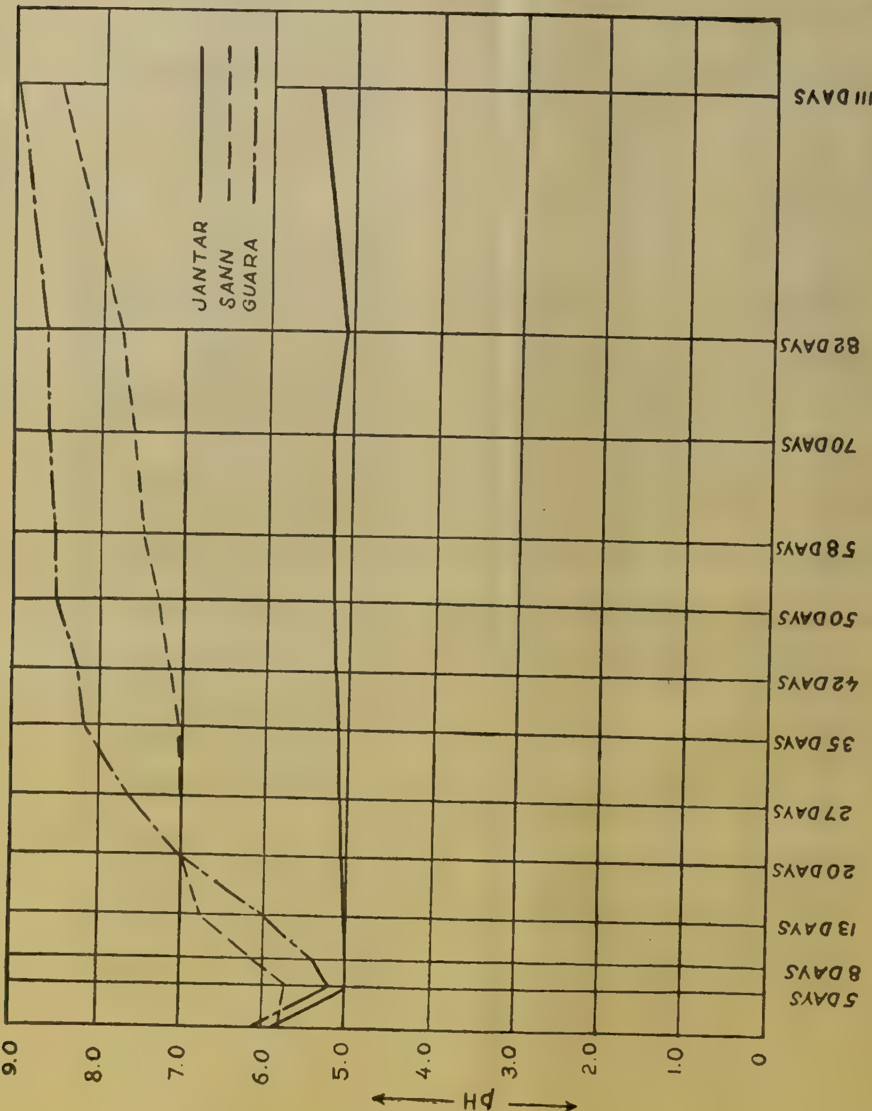


FIG. 5 (b) Variation in *p*H of leaf and stem juices combined in different green manures



Date of sowing : 22. 3. 54
Date of 1st cutting : 6. 5. 54
Date of extract of 2nd cutting : 26. 6. 54

FIG. 5(c). Variation in pH of leaf and stem juices combined in different green manures

The tests on the effect of green manuring with *jantar* on highly alkaline, clayey and impermeable soils were conducted at the Nissang Experimental Farm of the Research Institute. There is a vast area on the West of Karnal where the soil is very toxic to plant life on account of the presence of carbonate and bicarbonate of sodium and nothing has grown there for the last several decades. This land is entered in the revenue records as '*Ghair Mumkin Banjar*', i.e. barren, impossible to cultivate. Nissang Experimental Farm (Plate X, Fig. F) represents such areas. The results obtained with different types of soils are summarized below :

Jantar *green manuring on saline and water-logged land*

In *kharif* 1953 in plots I/3, L/2 and 3, N/2 and 3 and O/2-4 (Fig. 6), *jantar* was sown from early April to middle of May in tests carried out at the Indri Reclamation Farm. The seed rate used was at half the normal rate because there was not enough of seed of *jantar* available. In spite of this low seed rate, the *jantar* crop which was not very thick was green manured in early July, i.e. when it was two and half to three months old and about three feet high. After green manuring, rice was transplanted. The results of paddy yields obtained from the green manured plots together with the adjoining plots which were not green manured and where rice was sown only after preliminary leaching are given in Table IV. In all the cases, yields from the green manured plots are much higher than those obtained without green manuring, i.e. in the control plots.

TABLE IV

Yields of paddy obtained from different plots

Plot number	Area green manured			Area transplanted under rice			Yield of paddy obtained per acre	Remarks
	Acre	Kanal	Marla	Acre	Kanal	Marla	(in maunds)	
I/3	6	5	1	6	5	1	28·10	I. Set of adjacent green manured plots and non-green manured plots.
H/2	*nil*	*nil*	*nil*	7	2	4	25·0	
L/2 & 3	21	5	11	21	5	11	20·25	II. Set of adjacent plots.
K/4	*nil*	*nil*	*nil*	8	5	5	13·83	
N/2 & 3	13	0	0	13	0	0	17·5	III. Set of adjacent plots. The area was extremely hard and nothing grew without green manuring.
N/4	*nil*	*nil*	*nil*	2	6	18	0·40	
O/2-4	6	4	19	6	4	19	10·1	

This definitely shows the effectiveness of green manuring with *jantar* in increasing the yield in bad, saline and water-logged land.

Jantar *manuring on highly alkaline clayey and impermeable soils*

The effect of green manuring with *jantar* in highly alkaline clayey and impermeable soils was examined and compared with the control plots in tests carried out

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FIG. 6.—Plan of Indri reclamation Farm
(Scale 2″=1 Mile)

at the Nissang Experimental Farm. Besides green manuring with *jantar*, experiments with other treatments which could normally be applied after keeping the cost of each treatment in view for the reclamation of black alkali soils were carried out. Three sets of tests were made. The first set of trial was on semi-field scale with plots of the size of 3 ft.+6 ft. Three replications were made of each of the five treatments and of the control. The results are given in Table V.

TABLE V

Effect of green manure treatment on paddy yield

Plot No.	Treatment	Date of transplanting rice	Average height of plants in inches	Date of harvesting	Yield of paddy	Remarks and average for three replications
					Sr. Ch. Tola	Sr. Ch. Tola
B/1	*Jantar* green manured at 242 md. per acre	10-7-52	35	5-10-52	0 15 4	
B/7		10-7-52	35	5-10-52	1 0 0	0 15 1⅓
B/13		10-7-52	28	8-10-52	0 14 0	
B/2	Press mud at 242 md. per acre	10-7-52	30	5-10-52	0 14 4	
B/8		10-7-52	36	5-10-52	1 0 2	0 14 ⅓
B/14		10-7-52	26	8-10-52	0 11 0	
B/3	Control	10-7-52	28	5-10-52	0 11 1½	
B/9		10-7-52	25	7-10-52	0 9 1	0 10 ⅚
B/15		10-7-52	27	8-10-52	0 10 0	
B/4	Gypsum at 48·4 md. per acre	10-7-52	25	5-10-52	0 9 0	
B/10		10-7-52	23	7-10-52	0 4 0	0 6 3
B/16		10-7-52	21	20-10-52	0 7 0	
B/5	Farmyard manure fresh, at 242 md.per acre	10-7-52	30	5-10-52	0 12 4	
B/11		10-7-52	25	7-10-52	0 10 0	0 10 2⅔
B/17		10-7-52	26	8-10-52	0 8 4	
B/6	Farmyard manure rotten, at 242 md. per acre	10-7-52	30	5-10 52	0 12 2	
B/12		10-7-52	25	7-10-52	0 10 0	0 10 ⅓
B/18		10-7-52	26	8-10-52	0 7 4	

It will be seen from an examination of the results given in Table V that the *jantar* green manured plot gave much greater yield than the control plot. In fact the control plot gave little produce. Also the plots green manured with *jantar*

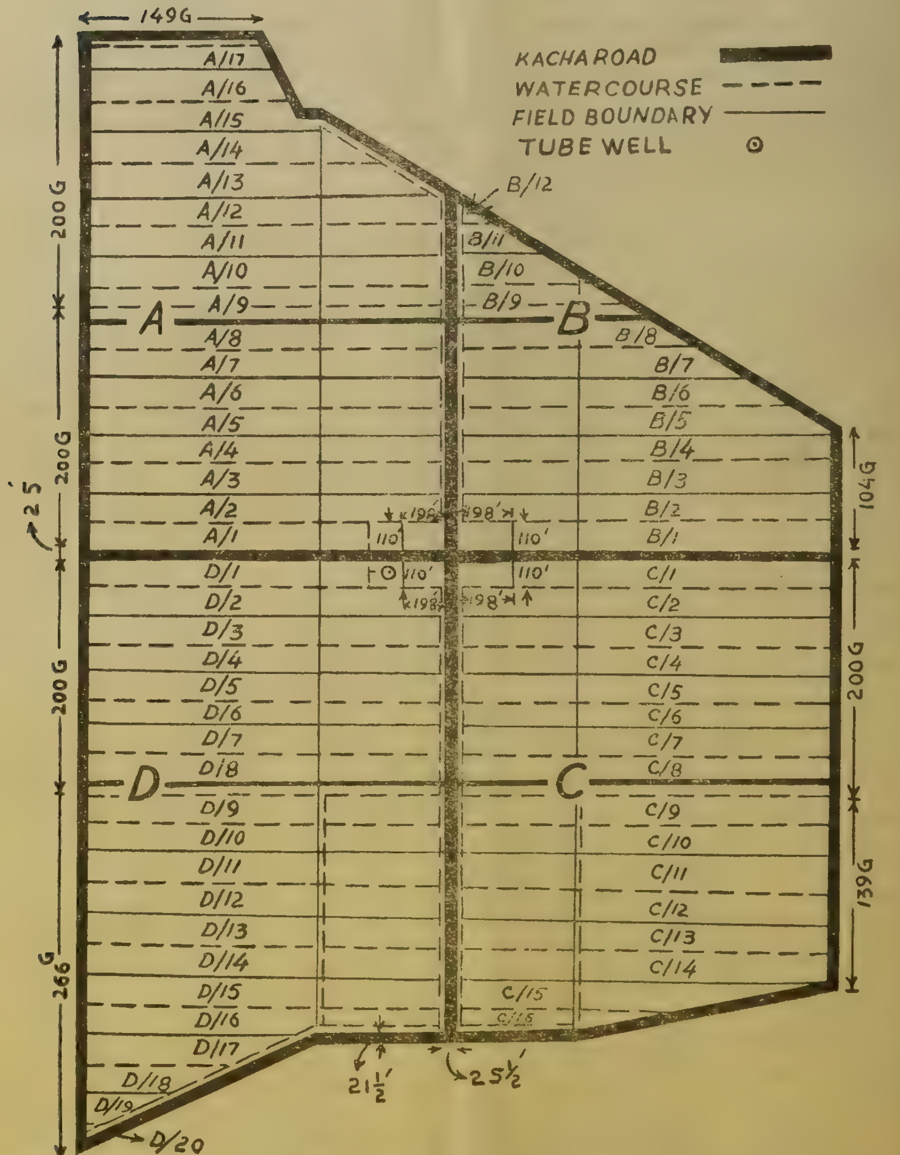

FIG. 7.—General Layout of the experimental reclamation station at Nissang

gave the highest yield as compared to the yield obtained with other reclamation measures. *Jantar* is much more effective than either the farmyard manure, fresh or rotten, or the gypsum or the press mud.

The other two sets which were tried at this farm were on field scale. The size of plots was 5/132nd of an acre and after leaving margin for the border effect, the actual area harvested was 1/40th of an acre. Four replications were made of each treatment which were applied in randomized plots. The different treatments examined were : *jantar* green manure, press mud, distillery waste (spent wash), farmyard manure and sulphuric acid. The results obtained are given in Table VI and VII.

TABLE VI

Results of different manurial treatments

Plot No.	Treatment applied	Date of transplanting rice	Average no. of tillers	Average height of the crop Ft.	In.	Date of harvesting	Yield of paddy per acre in md.	Average of 4 replications for each treatment in md.
Q1/5	*Jantar* green manure at the rate of 240 md. per acre	1-7-53	19	4	7	29-9-53	50·32	
Q1/8	do.	1-7-53	25	4	5	30-9-53	45·37	45·76
Q1/11	do.	1-7-53	14	4	7	5-10-53	41·50	
Q1/19	do.	2-7-53	16	4	8	29-9-53	45·84	
Q1/1	Control	1-7-53	7	3	4	30-9-53	12·70	
Q1/7	do.	1-7-53	5	2	11	3-10-53	2·50	10·44
Q1/14	do.	1-7-53	7	3	7	1-10-53	25·62	
Q1/17	do.	2-7-53	4	2	7	30-9-53	0·94	
Q1/4	Farmyard manure at 240 md. per acre	1-7-53	12	4	3	29-9-53	39·25	
Q1/9	do.	1-7-53	15	4	5½	3-10-53	37·44	37·62
Q1/15	do.	2-7-53	10	4	3½	30-9-53	43·50	
Q1/20	do.	2-7-53	8	3	11	30-9-53	30·31	

TABLE VI—(*contd.*)

Results of different manurial treatments

Plot No.	Treatment applied	Date of transplanting rice	Average No. of tillers	Average height of the crop		Date of harvesting	Yield of paddy per acre in md.	Average of 4 replications for each treatment in md.
				Ft.	In.			
Q1/2	Spent wash at the rate of 480 md. per acre	1-7-53	3	2	3	3-10-53	0·25	12·15
Q1/6	do.	1-7-53	5	3	½	3-10-53	6·56	
Q1/13	do.	1-7-53	8	3	7	1-10-53	30·40	
Q1/18	do.	2-7-53	6	3	2	29-9-53	11·38	
Q1/3	Press mud 120 md. per acre	1-7-53	4	1	10	3-10-53	11·0	18·97
Q1/10	do.	1-7-53	7	3	3½	..	19·0	
Q1/12	do.	1-7-53	8	3	11	..	32·0	
Q1/16	do.	2-7-53	7	3	8½	..	13·88	

TABLE VII

Results of different manurial treatments

Plot No.	Date of application and treatment	Average no. of tillers per plant	Average height of plant		Yield of paddy per acre in md.	Average of 4 replications for each treatment in md.
			Ft.	In.		
Q3/21	*Jantar* green manure at 240 md. per acre buried on 16-7-53	12	3	9	25·12	31·48
Q3/29	do.	13	4	3½	34·44	
Q3/34	do.	17	4	6	32·50	
Q3/36	do.	16	4	1	32·88	
Q3/22	Press mud at 240 md. per acre applied on 12-7-53	2	1	8	0·25	19·80
Q3/26	do.	11	3	11	25·38	
Q3/31	do.	8	3	11½	18·56	
Q3/37	do.	10	4	1½	35·00	

TABLE VII—*(contd.)*

Result of different manurial treatments

Plot No.	Date of application and treatment	Average no. of tillers per plant	Average height of plant Ft.	In.	Yield of paddy per acre in md.	Average of 4 replications for each treatment in md.
Q3/23	Control	6	2	7½	5·38	
Q3/27	do.	8	3	7½	15·94	
Q3/32	do.	8	4	½	21·75	14·19
Q3/40	do.	15	3	8	13·11	
Q3/24	Farmyard manure at 240 md. per acre applied on 13-7-53	6	3	5¼	13·62	
Q3/28	do.	14	4	5½	38·25	
Q3/35	do.	17	4	6	35·40	29·00
Q3/38	do.	12	4	0	28·75	
Q3/25	Sulphuric acid at ½ ton per acre applied on 17-7-53	4	3	1	5·81	
Q3/30	do.	9	3	8½	28·62	
Q3/33	do.	14	4	7½	32·87	23·40
Q3/39	do.	16	3	8	16·25	

It will be seen from an examination of Tables VI and VII that green manuring with *jantar* gives much better results than any other method.

7. *Effect of burying at different depths*

In the Punjab, very high temperature (118-120°F.) is experienced during the summer season which may burn the humus if it is near the surface. In order to find out the most suitable crop and the depth at which it should be buried, both in normal and deteriorated land—in the former case for increase of yields of the succeeding crops besides the period for which these increase in yields will remain effective while in the latter case the most suitable depth where the organic matter will show the maximum effect in the reduction of pH value and improvement of land—*guara*, sannhemp and *jantar* were green manured at the rate of 26 tons per acre at depths

of 5 in., 10 in., and 15 in. The results given in Table VIII show that *jantar* treated plots gave better yields.

TABLE VIII

Comparison of the effects of different green manures

Depth of green manure	Type of green manure used	Yield per acre
Inches		Md. Seer.
5	1. *Jantar*	49 36
	2. San	49 1
	3. *Guara*	46 20
10	1. *Jantar*	55 23
	2. San	49 1
	3. *Guara*	47 24
15	1. *Jantar*	49 1
	2. San	47 24
	3. *Guara*	46 20

Great depths of soil for green manuring are neither practicable nor economical. The results have been given for comparison only. The most suitable depth at which *jantar* should be buried is, however, six to nine inches.

Jantar has proved to be superior to all, giving larger number of cuttings, more of green matter, nitrogen and yield and greater acidic juice.

Statistical analysis of the data collected from the Field Experimental Stations at Indri and Nissang has been carried out. The results so far obtained show that *jantar* is more efficacious in effecting reclamation of saline and alkaline land. The correlation is significant.

Jantar is not only better suited for alkaline lands but for normal soils also. It should, therefore, be used more extensively.

Jantar can be sown from March to August. If sown in March, the first cutting can be taken in May, the second in July and the third in September for green manuring. Thus crop raised in one acre of land can be used for green manuring three acres of land. This is only possible when the crop is raised by irrigation, but it is more economical to grow *jantar* for green manuring purposes during the monsoon when it can give only one cutting. The seed ripens in November. After removing the seed the stem may be buried under water for about a fortnight and the fibre removed from the stalks for rope making. Thereafter it can be used as fuel or converted into compost.

Jantar can be sown in sandy areas where *guara* and sann-hemp would fail to establish. It can stand drought conditions as well as can flourish in standing water. In standing water it gives out lateral roots from the stem to have a firm grip in the soil so as to stand against strong winds.

There is a considerable increase in the yield of crops with green manuring. The maximum effect of green manure is noticed on the first crop. Its effect gradually diminishes as subsequent crops are taken. However, the effect of green manure on yields is visible even after a number of years. In addition to green manure, if artificial fertilizers like ammonium sulphate and superphosphate are used, crop yields will go much higher than those obtained with green manure alone. The increase in yield on account of green manuring with *jantar* has been observed in different States of India. For example in Bihar an increase of 106 per cent in the yield of wheat has been recorded. In Madras, the yield of paddy went up by 100 per cent and in West Bengal by 80 per cent.

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BOOK RECEIVED

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